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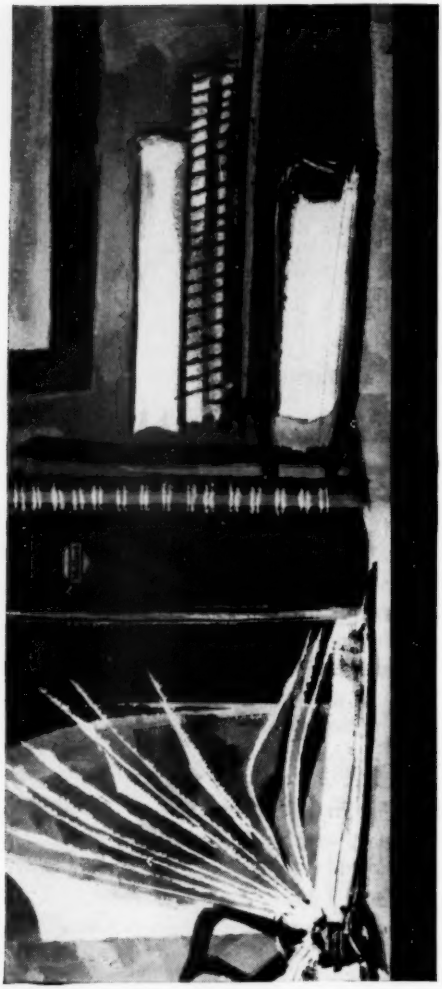

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A report of work done using grants from the Fund was given in an article in *Nature* (**187**, 733 (1960)). Examples of equipment constructed include an atomic beam magnetic resonance apparatus; a Wilson cloud chamber in which timemarks can be applied to the particle tracks at microwave frequencies; a high-speed integrating microspectrophotometer; a meniscus Schmidt camera for use in photographing meteors; various types of image devices such as solid state image intensifiers and X-ray image intensifiers; instruments for power measurement at microwave frequencies and for dating of archaeological specimens.

Applications may be submitted by any worker or group of workers in Great Britain. Applicants must be British subjects. Further particulars and application forms are obtainable from the Assistant Secretary, the Royal Society, Burlington House, London, W.1.

Facial eczema in New Zealand

It is now known that facial eczema, a photosensitivity disease of sheep and cattle in New Zealand is caused by damage produced in the liver by a poison in the fungus *Sporidesmium bakeri*, which grows on ryegrass in certain conditions of weather and season. The disease and its control are mainly of local interest, though of considerable economic importance in the North Island. But the publication of the recent reports of the investigation, now twenty, and dating back to 1942, is worthy of mention because it shows an admirable example of co-operation and perseverance in research. It was realised at the start that co-operation would be necessary: the story of the investigation has amply demonstrated this, and graziers, meteorologists, biochemists, biologists, veterinarians and mycologists, some from the U.K. at the request of the New Zealand workers, have all contributed their part, each essential in its place. The length of the investigation, the set-backs that were encountered, and the final success which promises an early solution to the problem, are a tribute to the painstaking application and the determination of all those who have been involved.

D. P. CUTHBERTSON

Nobel Prizes in Nuclear Science

The realm of science that underlies both chemistry and physics, because it deals both with particles and events that take place within the atom and even within the much smaller atomic nucleus, was recognised in the award of two Nobel prizes by the Royal Swedish Academy of Sciences during last December.

Professor Willard F. Libby of Los Angeles received the 1960 Nobel prize in chemistry for research which he began many years ago at the University of Chicago. When he began his work, it was well known that a chemical transformation can take place in collisions of swift particles such

as cosmic rays with ordinary atoms. When such a particle strikes an atom of nitrogen, for instance, one of the seven positively-charged protons in the nitrogen nucleus can lose its charge and thus becomes a neutron. This automatically releases one of the seven electrons at the surface of the atom. Having now only six electrons, the atom has all the chemical properties of carbon and is, in fact, a heavy atom of carbon. But the excess of energy that it took from the cosmic rays leaves the atom slightly unstable. Thus it becomes radioactive and slowly sends out the extra energy in the form of rays that can be detected easily even in very small amounts. The loss of energy by the rays is so slow that it takes 5568 years for the radioactivity to be reduced to half its original value.

The Atomic Time Clock

Dr. Libby's first achievement was the realisation that this process must take place in the atmosphere, eight-tenths of which is nitrogen and is exposed to intense radiation from outer space. In that case, he argued, a small proportion of the carbon dioxide in the air must contain atoms of carbon which have been formed from nitrogen and so must be radioactive. If so, it could be detected even in very small amounts when mixed with ordinary carbon dioxide. With a masterly refinement of technique and of instruments he proved that this is true.

It was his next thought that made this discovery so important. The carbon dioxide of the air, whether radioactive or not, is used by plants to build their structures—leaves, stems, wood, bark, root and seeds or fruits. The proportion of radioactive carbon, in comparison with ordinary carbon, must be the same in all living plant materials as it is in the air, since there is a constant interchange between them. What is more, animals eat the plants, and their tissues, made partly of carbon, must also have the same proportion of radioactive carbon. This proved to be correct.

But only until the plant or animal dies. Then the interchange with the atmosphere ends. The dead residue gets no more radioactive carbon from the air. But in the dead residue the process of radioactivity continues, growing less and less with the years as the radioactive carbon atoms lose their energy. After 5568 years the proportion of radioactive carbon to ordinary carbon will be only half of what it was in the living plant or animal. In another 5568 years it will again be reduced to one-half, hence to one-quarter of the original value. Thus Professor Libby devised an atomic time clock that can measure centuries back into the past and can reveal at what period any speck of organic material was alive—whether wood or seed, cotton or wool, leather or bone.

This method of counting age is accurate within about two centuries even as far back as 30,000 years ago. It has given the sciences of archaeology and of palaeontology a reliable time-scale for the history of living things through 300 centuries. It has been used to put a date on the Dead Sea scrolls, on ancient human skeletons and on mammoths and other animals that were long frozen in the mud and glaciers of the Arctic. Similar methods, using other chemical elements, are used to measure the age of the rocks of the earth's crust and even the age of the waters of deep underground lakes and of the bottom of the ocean.

The 'Bubble Chamber'

Dr. Donald A. Glaser, only 34 years of age, of the University of California at Berkeley, received the 1960 Nobel award in physics for his recent brilliant development of a new method for tracing the tracks of high-speed atomic fragments as they pass through matter, and thus for measuring their mass and energy. The particles themselves are far too small to be seen since they are very much smaller than an atom. But their path through matter can be made visible and photographed.

In an older method, the particle or ray condenses tiny droplets of water along its path through saturated water vapour; in another method, the tracks are recorded directly by their passage through a photographic plate.

In Dr. Glaser's new method the swift particles pass through a liquid, usually a very cold liquefied gas. In so doing, they create a thin line of very fine bubbles which can be photographed to tell the story of the particle that passed through or of the atoms that it hit, and what happened to them. Thus it is a method of recording events that are all over in less than a thousandth of a millionth of a second, and of identifying by their actions the still mysterious ultimate particles of which matter is composed—and perhaps energy too.

G. WENDT, *Unesco*

Staffing the Schools

The Year of Intermission

The year 1962 to 1963—which has come to be known as *The Year of Intermission*—is the year in which there will be no normal output of newly trained teachers from the general teacher training colleges because of the introduction in September 1960 of a three-year training course in place of the two-year course.

The three-year course will improve the quality of the teaching profession. The price to be paid for it is the loss for one year of most of the normal output of newly trained teachers for the schools. This loss will produce a year of exceptional staffing difficulties for the schools—especially the primary schools which, it is estimated, will be short of 9000 teachers in 1962–63 unless special measures are taken to fill the gap. From 1963–64 onwards the staffing position will improve as many more teachers come from the expanded training colleges and universities. The decision to introduce the three-year course was taken with the support of authorities and the teaching profession in full knowledge that it would mean some short-term difficulties for the schools. The difficulties are greater than could have been foreseen for two reasons: the birthrate started to rise again steadily, thus renewing pressure on the primary schools, and young women teachers started leaving their jobs earlier and in greater numbers to marry and have families.

Measures to improve the supply of teachers

It is the Government's policy to eliminate all oversize classes by 1970. It is estimated that this will need a total teacher force of 340,000. To ensure that this is achieved the Government has approved an expansion in the number of general training college places from 23,000 to 47,000. This means a building programme of about £36 million spread over some six years of building. It is hoped to have the whole programme completed by 1966, but schools will begin to get the increased supply of teachers from the earlier phases of the expansion programme before then.

Measures to find 9000 primary teachers

The most important measure is to persuade many more married women teachers to return to the schools for full-time or part-time service.

At present there are about 165,000 full-time women teachers in maintained primary and secondary schools. About 70,000 are married and of these about a third have returned to teaching since 1948 after a break in their teaching service.

The Ministry of Education foresees that a number of measures, including the following, may have to be adopted to improve the overall situation —an increase in part-time employment and in the employment of teachers over the retiring age, some movement of teachers from secondary to primary schools, and the use of refresher courses.

Erratum

Professor M. W. Thring of the Dept. of Fuel Technology and Chemical Engineering, University of Sheffield, and author of an article on 'The Role of Universities in Teaching Technology' which appeared in the January number of *The Advancement of Science*, was mistakenly and incorrectly described in that article as being a Fellow of the Royal Society. The Editor regrets and apologises for any embarrassment which may have been caused to Professor Thring by this error.

THE ACTION OF NICOTINE AND THE PLEASURE OF SMOKING

By Prof. J. H. BURN, F.R.S.

There may be some truth in the view that if we are anxious to study the action of drugs in the brain, we should study them as thoroughly as possible on the organs in other parts of the body, in the hope that what we learn may provide a key to the action of drugs in the brain. Certainly it is possible to reach tentative conclusions about the action of nicotine in the brain in this way. In the account which follows I will try to show how this can be done.

Nicotine on Skin Blood Flow

The effect of smoking on the blood flow in the hand was studied by Lampson in 1935, who used a plethysmograph, that is to say, an apparatus to record the volume of the hand. In this work he observed the rate of increase in volume of the hand when he raised the pressure in a cuff around the wrist. The raising of the pressure prevented the outflow from the veins. When the flow into the hand through the arteries was large, the hand volume rose steeply when the cuff was inflated and the outflow was stopped. But when the flow into the hand was small because the arteries were constricted, the hand volume rose much more slowly when the cuff was inflated. When the subject whose hand was in the plethysmograph smoked a cigarette, Lampson observed that the blood flow through the hand fell from 19 ml. for each 100 ml. of hand volume down to 4 ml., in the course of 7 min. The blood flow recovered during the next half-hour.

The effect of smoking a cigarette on skin temperature was studied about ten years later by Roth, McDonald and Sheard (1944). They kept their subjects for some time in a warm room, and recorded skin temperature by applying thermocouples to the skin. They found that when a cigarette was smoked, there was a rapid fall in skin temperature which ceased soon after the cigarette was finished and that some minutes later the temperature rose again. In an experiment of this kind performed by Irving S. Wright, the surface temperature of the finger tips was 32·7° C when the subject began to smoke. He then smoked one cigarette in 8 min., and at the end of smoking the temperature had fallen to 27° C. During the next 8 min. the temperature fell still further to 25·8° C. The temperature then rose again, and in 30 min. had risen to 32·4° C. Thus the smoking of one cigarette caused a drop of 6·9° C., or 12·4° F.

Explanation of the Vaso-constriction

These observations have hitherto been explained by the action of nicotine on the sympathetic ganglia. As is well known, the nerve fibres which run from the spinal cord to the blood vessels have a relay station on their course where one fibre ends and another begins. The relay station is the ganglion, and the fibre leaving the ganglion is the postganglionic fibre. If nicotine reaches the ganglion in the blood stream, it can cause a discharge of impulses along the postganglionic fibre. Indeed, this happens if a solution of nicotine is painted on the ganglion. Thus the effect of smoking in causing a diminution of blood flow in the hand, and a fall of temperature in the fingers has been believed to be due to the stimulation of the sympathetic ganglia by nicotine.

Difficulty in accepting this explanation arises in the first place from quantitative considerations. The amount of nicotine absorbed from a cigarette when deeply inhaled has been repeatedly measured, using an accurate biological assay (Ling and Wynn

Parry, 1949). The mean figure does not exceed 0·4 mg. Diluted in 5 l. of blood this amount of nicotine would be present in a concentration of one-twelfth of a microgram per ml. If we judge from experiments on spinal cats, the very lowest concentration which will stimulate sympathetic ganglia is one-third of a microgram per ml.

Action of Nicotine in the Rabbit Ear

Apart from these considerations which involve obvious assumptions, there are much stronger reasons for believing that nicotine has a different action which explains these peripheral constrictor effects. My former colleague Kottegoda (1953) studied the constrictor action in the ear of the rabbit. The ear was removed from the rabbit after death and then, when a small glass cannula was tied in the central artery, the ear was perfused with a modified form of Ringer's solution. The outflow from the veins was collected and changes in the rate of outflow were recorded by a sensitive differential device. Kottegoda found that amounts of nicotine (base) of the order of 3 μg., caused vaso-constriction when injected into the fluid flowing through the ear. He made two observations of great interest. When the substance tolazoline was added to the fluid passing through the ear, the effect of nicotine was reversed. It no longer caused vaso-constriction, but on the contrary it caused vaso-dilatation. The vessels expanded and the outflow increased. Now the substance tolazoline has long been known to change the action of adrenaline from a constrictor action to a dilator action, and in the vessels of the rabbit ear it has the same action on noradrenaline. Kottegoda's finding that in the presence of tolazoline, nicotine caused dilatation and not constriction, suggested that nicotine might exert its constrictor action by the release of adrenaline or noradrenaline. Perhaps there was, in or near the vessels of the rabbit ear, some store of adrenaline or noradrenaline on which nicotine could act, releasing a portion of the store. Thus the constriction caused by nicotine might not be due to the nicotine itself, but to the noradrenaline which it released. His second observation showed that if this was true, then the store was in the skin. For he removed the skin from the underlying cartilage on which there remained a network of vessels. When these were perfused, nicotine did not cause vaso-constriction; its effect was slightly vaso-dilator.

The Action of Reserpine

Kottegoda's results, obtained in 1953, could not be extended at that time. But in the same year the properties of reserpine, an alkaloid from Rauwolfia serpentaria, were described by Bein, Gross, Tripod and Meier (1953). Three years later Bertler, Carlsson and Rosengren (1956) showed that reserpine discharged the store of noradrenaline in the isolated heart. The existence of a peripheral store of noradrenaline was shown in the arteries and veins of the ox and horse by Schmiterlöw in 1948. The existence of a store in the heart was shown by Goodall in 1951, and of a store in the spleen, liver, kidney and salivary glands was shown by Euler and Purkhold also in 1951. Bertler, Carlsson and Rosengren tested the effect of injecting reserpine on the store of noradrenaline in the rabbit heart. In the hearts of normal rabbits they found a mean amount of 1·53 μg./g. If however rabbits were killed 16 hr. after the injection of reserpine, the hearts contained a mean amount of only 0·03 μg./g.

We therefore proceeded to test the effect of injections of reserpine on the mean amount of noradrenaline in the thoracic aorta of rabbits. We observed the same change as in the heart. While the thoracic aorta from normal rabbits contained 0·47 μg./g. noradrenaline, that from rabbits injected with reserpine contained less than 0·11 μg./g. This led us to investigate the skin of the rabbit ear to see if we could detect the presence of noradrenaline in it. We were able to determine that a mean amount of 0·1 μg./g. was present, while in rabbits injected with reserpine the amount was only 0·03 μg./g. or less.

Nicotine in the Perfused Ear after Reserpine

At this point it remained to observe the effect of nicotine in the perfused ear of the rabbit which had previously been treated with reserpine. We found that nicotine had no vaso-constrictor action. The result was repeatedly confirmed. We also made observations on isolated strips of the thoracic aorta of the rabbit. When suspended in a bath, the strips were found to contract on the addition of nicotine to the bath. When the strip was prepared

from a rabbit previously injected with reserpine, the addition of nicotine failed to cause a contraction.

From these results it was clear that nicotine had an action in the vessels of the rabbit's ear where it caused vaso-constriction by the release of either noradrenaline or adrenaline. Our results did not permit us to distinguish between noradrenaline and adrenaline, but in view of Schmiterlöw's findings of noradrenaline in the vessels of the horse and of the ox, we thought the substance was more likely noradrenaline.

Observations in the Heart

Similar observations were made when the atria or auricles were dissected from the rabbit heart and allowed to contract in a bath. In the presence of atropine, nicotine caused acceleration of the rate of beating and increase of the amplitude. But when atria were prepared from rabbits previously treated with reserpine, then nicotine had no effect on either rate or amplitude. Thus it appeared that the stimulant action of nicotine was due to the liberation of noradrenaline, since it was exerted only when noradrenaline was present.

Observations on Erection of Hair

It is possible to watch the erection of hair on a cat's tail by clipping off most of the hair, so that only a few tufts remain on the dorsal aspect of the tail. Coon and Rothman (1940) showed that when nicotine was injected into the skin at the base of the tuft, the tuft was erected for a short time. We were able to confirm this observation and to show that if the cat was previously treated with reserpine, the effect of nicotine was greatly reduced. We also extracted the skin of the tail and tested the extract for noradrenaline; the skin was found to contain 0·35 μg./g.; when the cat had been treated with reserpine, the skin then contained only 0·057 μg./g. Thus the evidence here also was consistent with the view that nicotine caused erection of the hair by releasing noradrenaline from the store.

Observations in Other Organs

The same situation was also demonstrated in the nictitating membrane of the cat's eye. This is another sympathetically innervated organ which can be removed from the body and studied in isolation, as Thompson (1958) has shown. The normal membrane is caused to contract by nicotine, but if the membrane is removed from an animal previously treated with reserpine, nicotine is then without action. It can be assumed that here also the contraction caused by nicotine is due to the liberation of noradrenaline.

Another organ which has been studied is the colon of the rabbit after removal from the body. Nicotine in low concentration causes relaxation of the muscle. It has the same action in the presence of atropine even in high concentration. This relaxation is also due to the liberation of noradrenaline, since it is absent if the colon is taken from a rabbit previously treated with reserpine (Gillespie and MacKenna, 1960).

General Conclusion

These observations do not complete the story, but they provide clear evidence for the general statement that nicotine acting on isolated tissues from which the recognised sympathetic ganglia are absent, exerts an action like that of sympathetic stimulation. This action resembles the effect of sympathetic stimulation because it is exerted by the liberation of noradrenaline.

Noradrenaline in the Brain

In 1954 a very important paper on the distribution of noradrenaline in the brain was published by Dr. Marthe Vogt. The presence of noradrenaline in the brain had been shown by Euler (1946) and by Holtz (1950), but Dr. Vogt made a detailed study in which she used methods sufficiently sensitive to detect concentrations as low as 0·01μg. noradrenaline and 0·005 μg. adrenaline per gram of fresh tissue. Her final determinations were made by specific biological methods and could not therefore suffer from the error of including biologically inactive material or material other than noradrenaline or adrenaline in the estimate. She found the highest concentration of noradrenaline, 1·03 μg./g., in the hypothalamus. After the hypothalamus the next highest concentration was around the aqueduct of Sylvius, and there was not much less in other parts of the midbrain. The more cellular parts of the medulla contained about one-third of what was in the hypothalamus. The only other part of the brain containing a moderately

high amount of noradrenaline was the medial part of the thalamus. All cortical areas contained very little.

The Seat of Consciousness

It would be out of place here to discuss the part of the brain which is essential for consciousness. It is not the cerebral cortex, but rather the hypothalamus and brain stem (Jefferson, 1944). This question has recently been reviewed by Feldberg (1959). It is sufficient to say that the area essential for consciousness coincides to a great extent with the location of noradrenaline. Now Holzbauer and Vogt (1956) showed that when cats were treated with reserpine, the noradrenaline was greatly reduced in amount in the parts of the brain which have been described. When animals are treated with reserpine there is a great alteration of mood. Fierce and aggressive animals become tranquil and calm. If the treatment with reserpine is continued, the animals become depressed and listless. This state of depression is quite possibly, or some would say very probably, related to the disappearance of the noradrenaline. If that were so, we might expect to be able to relieve the depression by giving noradrenaline. The difficulty about this is that noradrenaline when given by intramuscular or even intravenous injection, does not easily enter the brain. There is what is called a blood-brain barrier, which hinders the entrance of many substances into the brain, and noradrenaline is one of these. However Carlsson, Lidqvist and Magnusson (1957) showed that the substance from which noradrenaline is formed, namely the amino-acid 3-4-dihydroxyphenylalanine, could be given by injection and was able to arouse mice depressed by reserpine and restore them to normal activity, making them for a time excessively active. This indeed suggests that the depression produced by reserpine is due to the disappearance of the noradrenaline which is normally present.

It should be stated here that reserpine not only depletes the brain of noradrenaline, but depletes it also of another amine, hydroxytryptamine, and some consider that the state of exaltation or depression depends on the concentration of hydroxytryptamine. However, neither the giving of hydroxytryptamine nor of its amino-acid precursor hydroxytryptophan, relieves the depression caused by reserpine, though it was found that a combination of both the amino-acids which are precursors of noradrenaline and of hydroxytryptamine was more effective than the precursor of noradrenaline alone.

The Effect of Nicotine

If mood and the state of alertness depend on the concentration of noradrenaline in the brain, it becomes reasonable to suggest that nicotine, which enters the brain readily, produces much of its effect by liberating noradrenaline from the store, for we have seen that it has this action in many other places where a store of noradrenaline is present. Indeed we know already that large doses of nicotine release noradrenaline from the store in the brain, for this was demonstrated by Dr. Marthe Vogt in the course of her work. She showed that nicotine in amounts of 4 mg. per kg. or more (reckoned as base) depleted the noradrenaline in the hypothalamus to 64 per cent of its normal value in the course of 4 to 6 hrs.

The Reasons for Smoking

There are of course many reasons for smoking cigarettes. One is a liking for the fragrance of the burning tobacco leaf. Another is a liking for the air of elegance which the handling of the cigarette can impart. Another very important reason is to give an appearance of calmness and detachment under conditions which are in fact disturbing. It is difficult to say how far the effect of nicotine on the brain is involved in any of these. But the smoking of cigarettes, especially when we are alone, provides stimulation when we wish to concentrate attention on a problem. Above all the smoking of cigarettes freshens the mind of those who are tired and enables them to think with greater clarity when they are suffering from lack of sleep. This stimulating action on the brain is precisely what would be expected if nicotine was acting by liberating noradrenaline from sites in the hypothalamus, midbrain and medulla. Not only nicotine can do this. Amines such as amphetamine (also known as Benzedrine) act like nicotine on the heart and blood vessels and release the store of noradrenaline. They no longer accelerate the heart, or cause a rise of blood pressure in animals treated with reserpine in which the stores of noradrenaline are absent.

We may therefore assume that amphetamine releases noradrenaline from the stores in the hypothalamus, and it is in part at least by this action that amphetamine enables a man to work continuously for 48 hr. without having sleep. In my title I spoke of the pleasure of smoking. We are beginning to form a picture of how mood may depend on the presence of noradrenaline in those areas of the brain which maintain consciousness, and how certain substances of which nicotine is the most important, can stimulate us and elevate the mood by raising the concentration of noradrenaline. This at least gives a hypothesis by which to guide our further experimental studies.

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MARINE FISHERIES: THEIR CONSERVATION AND THEIR POTENTIAL

By **Dr. C. E. LUCAS, C.M.G.** *Director, Marine Laboratory, Aberdeen*

The sea is still our major highway; it is the very active natural boundary of all our lands, with all that signifies, and an almost incalculable natural source of power. With the atmosphere, it controls our weather and influences our climate; it is also a natural solution of almost all the chemical elements and an extraordinary variety of inorganic and organic compounds. As the envelope of a sea-bed covering 70 per cent of the earth's surface, it must be as rich or richer in minerals as the land. In addition, it is the source of our valuable marine fisheries, and it is with these that this paper is concerned, but the other aspects of the sea's significance are relevant!

The problem of the fishermen in taking their catch is a very difficult one. It is as though hunters on land set out to catch, with very small nets, not birds they can see and whose habits they and their fathers have observed for generations, but birds which are only available in the dark, and which flock according to habits and reactions which are only revealed by the almost random shooting of their nets.

Until very recently, this was the fishermen's and the scientists' chief problem. Both had to work in the dark! Just before the war science began to help with the adaptation of the echosounder for 'seeing' fish as well as the sea bed. Since then scientists have used it with the underwater camera and television, to see fishing gear as well, and even fish actually being caught; but the fisherman still needs all the aid he can get, for not only is fishing a difficult task but the sea is a vast, relatively unexplored and largely unexploited area. The knowledge we already have of the seas and their resources is a tribute to the skill of the fishermen and the scientific progress already made, but with the vastness of the oceans and their potential value in view, both the harvest and the scientific effort are too small. Except during the wars, over the last fifty years, Britain has taken each year about a million tons of fish from the north-east Atlantic: its present value at first sale about £50 million. During that time the whole European catch increased, and it stood at some eight million tons in 1957, when F.A.O. estimated the world's marine catch at 27 million tons, compared with nearly 19 million in 1938. These figures are themselves impressive enough until we compare them with those for agriculture: for the world, around 1000 million tons of vegetable produce and probably 50–100 million tons of animal protein. So, despite its size, the sea's present yield is not so impressive after all; and it is chiefly this fact that has limited our research and exploratory investment. Yet, despite over-fishing in a few regions, we evidently had a long way to go in 1938 and the slope of the post-war curve suggests that we still have. There is moreover, another way of looking at this marine harvest; in terms of the yield per fisherman, it can compare very favourably at times with the agricultural yield per man. Why is it then that we get so little from the seas compared with the land? There are, of course, many reasons, among them the problem of distributing the catch to populations far from the sea. Primarily, however, it is because we are still very old-fashioned and unscientific in our exploitation of the sea. This is neither a criticism of the research worker nor of the hard-working fisherman. The fisheries scientists must necessarily direct most of their effort to the problems of the industry as it exists, while the fishermen can only afford to fish for profitable markets.

The conventional fish stocks are based on the continental shelf, where the upwelling of nutrient-rich water supports the floating plant and animal plankton on which all fish directly or indirectly depend. The fish fluctuate in abundance, largely in response to fluctuations in the strengths and directions of the ocean currents, and in the plankton which 'supports' them and the animals of the sea bed. In close association with climatic changes, these fluctuations provide the familiar environmental influences on the stocks. But their abundance also depends on man himself, with his frequently wasteful fishing.

For it has been characteristic of almost all kinds of fishing that success has usually led to ruthless exploitation until the stock has been unable to recruit and grow as fast as man has reaped. That has been followed by diminishing returns of smaller and smaller fish until economics or war forced a reduction in the fishing intensity. In slowly reproducing animals such as whales, this has led to near or even complete extinction, but fortunately most fish stocks are resilient and respond rapidly to a reduction in fishing.

These matters are among the objects of study in marine biological and fisheries laboratories. With, until recently, very small staffs and converted ships, some of the general principles governing the main water movements have been unravelled: the more obvious variations of regional fertility and some of the secrets in the lives of our principal fishes and their food organisms. In particular, for a number of fish, precise censuses are being maintained: of ages, annual recruitment, growth, mortality, etc. These, together with estimates of fishing intensity, are now permitting assessments of the effects of fishing upon some of the best-known stocks and some predictions of their future, naturally and under modified conditions of fishing. These are no mean achievements and have been skilfully drawn from great accumulations of data. They have a substantial basis of theory which is itself a major contribution to animal population studies. We now know that overfishing occurs when a stock is fished so hard that the young do not live long enough for it to reach its maximum weight: and underfishing when they are allowed to survive beyond that weight. By agreement on an international fishing policy the optimum stock could be maintained, and in recent years several international commissions have been set up with the object of exploiting the stocks to their best advantage, according to the scientific evidence.

In all this work, the two British fisheries laboratories have been in the van. Unfortunately, there is not space here to describe the work of those laboratories and others, in studying the aquatic environment and predicting its influence on the fish and their food; on the reactions of fish to their environment and to fishing processes; in analysing the operations of conventional fishing gears so as to improve on them; and in pioneer studies of productivity in the sea and the factors influencing the early lives of fishes. It is necessary to take a view of something more than just the conventional fisheries: rather of how these fisheries and others might be developed, and even a little of unconventional developments, with world needs in view.

Valuable advances have been made since the war, particularly in the field of conservation. Broadly speaking, these advances have been based on scientific capital banked before the war, in fisheries laboratories and in general marine laboratories such as the National Institute of Oceanography and those in Plymouth and Millport, scattered mainly round the northern Atlantic and Pacific Oceans. Elsewhere, such laboratories are very few and we have to rely for information about the southern oceans, and much of the more distant northern waters, on national expeditions among which our own *Challenger* and *Discovery* Expeditions have played honoured roles. Viewed in relation to agricultural and industrial research, the whole is pathetically small. Yet it has given a general picture of the sea and its riches which demands further investigation and exploitation.

The sea occupies over 70 per cent of the world's surface and, like the land, has its natural crop of plants and animals, which varies considerably from place to place. We now know that its overall productivity, in terms of plant matter, is at least as great as that of the land, probably more than 100,000 million tons per annum. But there is an important difference; on the land, most of the basic production is in terms of grass, trees and other plants which are often directly utilisable; with the exception of the seaweeds, production in the sea is based on countless myriads of unicellular plants, from which vast crops might be taken,

except that they are individually so small that we do not know how to reap them. At present we have to rely on the fish and whales to reap them for us, mainly via the small animals which feed directly on the plants, and with them form the plankton. Only in a few instances do we know much of the food chains in the sea, forming an extraordinarily complex network in time and space. But we do know that there is a great loss in productive efficiency at each stage, i.e. between the plants and the small animals that feed on them, between these animals and the larger ones, and so on; perhaps 80–90 per cent in each step. So that the original 100,000 million tons (+) of plant matter produced is probably reduced to about 1000 million tons (+) of animals of a size conventionally acceptable as human food. Yet that is far greater than the 30 million tons caught at present. Not all these animals are fish, of course, but a large fraction of them are; of the others many are representatives of animal groups which already provide food in one part of the world or another.

Considered from this position, can we be satisfied with a production of 30 or even 50 million tons of fish? In food terms alone, the sea is a potential source of protein far too valuable to be taken in the present somewhat primitive way! And when we consider its food potential along with those other important characteristics mentioned at the beginning, can we afford any longer to treat marine research as almost the Cinderella of the sciences? Does it not deserve a place among the major basic and applied fields of investigation? But meanwhile, let us consider in rather more detail just what are the potential food supplies we can anticipate from the sea, and how reasonably we can look forward to their contributions.

In the first place, even from our present fisheries, we can look for valuable increases if our present knowledge can be applied internationally for conservation. And the contribution which population studies already offers is by no means limited to those fisheries which are over-fished. It applies equally to the fisheries which have yet to be fully developed, and, of course, to all those which have yet to begin and which each run the risk of ill-considered exploitation. For the aim is rational exploitation, the maximal sustainable yield of the species and qualities most desired, with consequent economy of human effort and investment.

Fishery Research Vessel 'Explorer' of the Department of Agriculture and Fisheries for Scotland, Marine Laboratory, Aberdeen. *(Photograph—N. T. Nicoll)*

In the second place, some of these fisheries are capable of further exploitation as markets are developed. Particularly on the other side of the north Atlantic, the curve of production can certainly go farther in several cases, so long as the countries which have signed the appropriate fisheries convention are prepared to control their fishing as it reaches the optimum point. In the north Pacific, too, the rapidly rising yield curve suggests that more can be expected of several fisheries; Japan has nearly doubled her catch since 1938, as also has China. Of the southern oceans, we are less certain; their overall production of fish will probably prove much less than that of the northern hemisphere, with its vast continental shelves. But South Africa, for example, has increased its catch of sardines from *ca.* 50,000 tons in 1938 to 400,000 tons in 1958, following the scientific demonstration of the richness of the local waters and the spawning locality of the sardine. Even more dramatic is the very recent rise of the Peruvian anchovy fishery to well over one million tons, and research suggests that this fishery can provide still more.

Next there is the conservative nature of the fishing industries of the world. Although slowly changing, under the impact of science and technology, they are very traditional in their methods and in their objectives. This is in part a reflection of our conservatism in food matters. Thus it is that some fish are popular in England and not so much in Scotland, and *vice versa*. The redfish, or soldier, is well esteemed in several countries, yet we almost neglect it; similarly, we neglect the mackerel, while we import pilchard and tunny in the expensive form of tins. Yet quantities of all are available not too far afield. We, in turn, esteem the halibut, but fishermen of some European countries actually reject it—and so it is over a wider field. In all instances where a fishery is not already near the optimum yield, a change in culinary fashion and the development of a market, could lead to an increase in the national and, ultimately, the world's food supply.

These are conventional fish on conventional fishing grounds, but there are conventional fish to be found on grounds which have been wholly or partly unexploited. For example, the oceanic distribution of the young redfish and the rapid development of new tunny fisheries suggest that their yield could be increased. Even more is this the case with fisheries in many undeveloped countries, where research and technology offer major advances. In few regions would a greater animal protein supply be more useful than around the Indian Ocean. But most fishing there is limited to what can be caught a little way off shore by unpowered boats and primitive techniques. Yet what is known suggests the possibility of great stocks of the local species of sardine. Indeed, it is on such pelagic as distinct from demersal fisheries, in the open ocean as distinct from nearer the shores, that some of the major potential of the sea now lies. There has been a tendency to regard the plankton supplies of the open ocean as relatively inadequate for major stocks of commercial fish, but recent evidence concerning ocean currents and their upwelling more or less in mid-ocean—and concerning the oceanic plankton itself, as the Oceanographic Laboratory in Edinburgh is showing—is causing a revision of these views. Here and there, as with tunny, fisheries are developing to confirm the predictions on which they were launched.

In addition, we can also look forward to some completely new fisheries, at least for conversion to fish meal if not for direct human food; and this could free for human consumption conventional fish such as herring which are being unnecessarily taxed for such uneconomic purposes as animal feeding. Here we can have in mind the great shoals of smaller fish which are often the food of our larger ones. Some of these, such as the sand-eel and the Norway pout are already being sought, but there are many others, such as the Arctic capelin, the Atlantic blue whiting, and the various fish which contribute to the world-wide echo-scattering layers. With the aid of research now proceeding on fishing gear, these may yet increase our catches several times.

The fisheries are usually said to be in the hunting phase of development, and in the main this is true. Yet we all know that oysters are cultivated and several other molluscs. Much more important, however, is the fish cultivation which has been maintained empirically in the east for thousands of years, and is now being developed more scientifically in a variety of mainly tropical and sub-tropical localities. If much of this is in fresh water, there remain great possibilities for the further cultivation of coastal swamps and waters—

and particularly in those areas where animal protein is greatly needed. Further developments can be expected as basic research in this field moves from the simpler investigation of the principles of optimum cultivation, through the advantages to be gained by physiological techniques for improving reproduction, growth, etc., to the breeding of the most suitable varieties for different purposes.

We must, however, consider the limitations as well as the possibilities of cultivation. In particular, the fish we most appreciate are carnivores, but the most successful fish in cultivation are herbivores. This is the explanation of the great yield of some fish farms, a ton per acre per year and more; in terms of carnivorous fish this yield might be reduced to a tenth because of the metabolic losses involved. Valuable pioneer experiments were made in Scotland during the war which deserve to be done again, if only to have them cost-accounted and to gain more knowledge of the pros and cons. Any suggestion that the seas should be fertilised wholesale, however, must face the fact that they already contain much of the world's stock of fertilisers. Indeed, there is the possibility that we may yet find a means of bringing the deep stores of nutrients into the sunlit plankton zone by artificial upwelling. Meanwhile, to broadcast fertilisers over the seas would be rather like random manuring of the land, in order to increase the yield of lions and tigers! The bulk of the fertiliser added would be taken by a host of predators lower down in the marine food pyramid, before the desirable carnivores and many of the omnivores were reached. This is not to say that *ad hoc* fertilising or the addition of selected growth substances in selected marine areas at specific times may not prove economic. But meanwhile there is more immediate hope in the rearing of some small fish in controlled conditions for subsequent 'planting-out' in the sea, as the Fisheries Laboratory at Lowestoft is proposing, and in transplanting from poorer to better natural waters, as has also been tried. There are also prospects in the careful selection of species for permanent colonisation of waters in other parts of the world, and in the experimental breeding of new varieties with improved growth rates or some other desirable qualities. Again, there may be possibilities, as Sir Alister Hardy has suggested, in weeding out undesirable competitors and predators in certain situations. But both with colonisation and 'weeding' we need to know much more about the ecological consequences of such acts, before casually adopting them, and here is just one field in which much more research is urgently needed.

No more than mention can be made of the possibilities of cultivating plankton, nor of the chemicals and pharmaceuticals we may yet take from the sea or from sea life, but there are also the distant but enormous possibilities of the natural plankton. Even now the larger zoo-plankton is caught and eaten in some parts of the world where circumstances are particularly favourable, but in general we have not yet the means to reap it. In the richer areas, however, such as the polar regions, the annual production presents a challenge which may some day be accepted. At present we can merely set against the difficulties and the costs, and the fact that whales and fish harvest plankton for us freely, the loss we incur by taking less than 0·1 per cent of the total marine production! To acquire that fraction the world uses over a million vessels of various sizes and perhaps some four million men. Some day, when the incentive is great enough, as for many 'miracles' it was during the war, some of us will decide that such an effort deserves a greater return and therefore a major attempt to see whether a solution cannot be found.

The sea, then, at present gives us some 30 million tons of animal protein, etc., and we can have every confidence in that being doubled by the simple application of present knowledge and techniques. It is important that most of that increase should be in areas where the need for animal protein is greatest. But the prospects are such that we can also be sure of considerable increases for the more advanced countries, given the demand and the markets.

These potentialities are certain. They are of the kind which have enabled major fishing countries such as Japan to treble their catch within a lifetime, but further knowledge would open the way to a much larger harvest. This is one aspect of our urgent need for a knowledge of the biology of man and the animals and plants on which he depends, which will prove no less important than the basic physics and chemistry of the world from which we have already gained so much. Of none of our resources is this truer than of the sea, where we

need a detailed knowledge of the ecology of all the major forms of marine life; and none, whether we think of food or more material matters, more deserves a major research effort, in this country and elsewhere.

Of our own effort, I would merely say that it has, so far, nothing to be ashamed of: rather the reverse! There are few of the early lines of marine or fisheries research in which you will not find a leading or major role played by British scientists, and this remains true of most of the growing points of marine research today. But the sea's wealth has not gone unrecognised abroad. We have always acknowledged the high quality and wide range of marine work proceeding in several continental countries, in the U.S.A. and in Japan. But now they with the U.S.S.R. and Canada, are making plans for marine research which promise to leave us behind. Fisheries, and marine research in general, are the most international of sciences, and the most rapid progress will be by international co-operation. But we cannot leave either the research plums or the first development of the undoubted commercial plums, to be acquired by others and merely adapted or copied by us. There are rich rewards to be won, however you may look at it, for a relatively modest increase in marine research—so long as we plan our exploitation rationally. Moreover, there are vast unexplored spaces off our coasts which are intellectually and physically as exciting as any; we know less of the sea bed than we do of the face of the moon. This space could provide ample food for the mind and in due course for the body.

THE MAIN LINES OF MATHEMATICS

By **Prof. J. L. B. COOPER** *University College of South Wales and Monmouthshire*

Although almost everyone is taught some mathematics, only a small proportion of educated people have even a vague idea of what the subject is about, as they know that physics is about matter or zoology about animals. Most people either confuse mathematics with applied mathematics—and let me explain, to avoid this confusion, that I am using the word mathematics in its strict, and indeed its only logical interpretation, to mean pure mathematics—or think that it is not about anything at all, but it is a farrago of rules of calculation, such as one encounters in elementary arithmetic, a rather distasteful preliminary to really interesting pursuits such as keeping accounts, doing the pools or learning engineering. This attitude develops into and is encouraged by some prevalent theories of mathematics: the word farrago, indeed, is one I have borrowed from Wittgenstein. Without doubt these theories have the effect of laying an exclusive emphasis on the most uninteresting parts of mathematics, manipulative techniques and the learning of notation; and one can hardly doubt that they contribute to the mechanistic and rule of thumb methods of teaching the subject which are in evidence in so many schools and are complained of in several recent reports on secondary school mathematics.

These theories have behind them the authority of the most fashionable modern school of British philosophy, that of linguistic analysis, and of its predecessor, logical positivism; and with their backing have penetrated all sorts of diverse fields, up to aesthetics, literary criticism and the brains trust. So widely held are they that it would be just to describe them as a folklore about our subject.

The best-known phrase from this folklore or mythology of mathematics is the sentence 'Mathematics is a language'. This is not, to be exact, a tenet of any philosophical school. It is far too imprecise for that. Even with all the possible twists one can give to the meanings of the words 'mathematics', 'language' and 'is' it is hard to find a sense which does not make it either absurd or trivial. Literally, it is certainly absurd. It is characteristic of a language that it has no concepts of its own, that anything said in one language can be translated into another. A statement in English, when expressed in French, is no longer an English statement; but a mathematical statement cannot be made into a non-mathematical statement by any translation, while perfectly good mathematical statements: for instance: 'the sum of the angles in a triangle is two right angles', 'given any prime number, there is a prime number larger than it', can be expressed, as here, in perfectly good English, and remain the same when expressed in Russian, Greek or Japanese as far as mathematical content is concerned. As far as I know the origin of the phrase is an aphorism of Willard Gibbs, 'Mathematics is the language of the Sciences'; but this is a statement about the sciences, not about mathematics, just as the sentence 'English is the language of Shakespeare's plays' is not a description of the English language. What it means is that mathematics has a highly developed notation of its own, which is used in the other sciences; and this is clearly true, unless it is misinterpreted into an identification of mathematics with its notation.

The underlying meaning of the phrase, 'mathematics is a language', is that mathematics has no content of its own. This is expressed with greater precision in positivist and related philosophies by saying that mathematical theories are purely a matter of definition, or consist of a set of tautologies; or, and this comes to much the same thing, that in a mathematical system the truth or falsity

of the statements made depends only on the form of the statements, just as the grammatical correctness of an English sentence is determined by the form of the sentence in relation to the rules of syntax; it is this last formulation which links this view with the linguistic theory of mathematics.

To understand the degree of truth, and the errors, in these theories we must consider the structure of a mathematical theory if it is presented in an ideally exact form. Suppose that we have such a theory—say the theory of the integers, or Euclidean geometry, to give examples—set out with the greatest possible precision and rigour. We should find, to begin with, that the theory had a set of words or concepts in terms of which all the other expressions of the theory are defined: for since any concept can only be defined in terms of other concepts, and the process must start somewhere, there must be some terms which are not defined: these we call the undefined terms of the theory. Next we find a set of initial assumptions, or axioms of the theory, which take the form of a set of statements about the undefined terms. The theory itself then follows in the form of a chain of logical arguments proceeding by deduction step by step from the axioms, every step being a statement implied by the axioms and the statements previously proved.

This procedure is not quite exclusive to mathematics. It can equally well be followed in other disciplines, and is sometimes found in works on mathematical physics, in particular in dynamics, though a strict axiomatic procedure in which no assumptions are introduced apart from the axioms which are stated initially is rare outside mathematics. There are, however, two crucial differences between an axiomatic system in mathematics and one, however strictly carried through, in physics. The first is that in mathematical physics some at least of the undefined terms are intended to be names of specific things or relations in the physical world and the second is that the validity of the system depends on the correspondence between the deductions made within the systems—the theorems of the system—and the observed behaviour of these physical things. The correspondence may be pretty remote and abstract, in the most developed theories, but it must in some sense be there. In a mathematical theory, on the other hand, the undefined terms need not be the names of specific things, and no observational evidence can, therefore, affect the validity of the theory.

The classical example of a mathematical system is Euclidean geometry. In its traditional form the words used in the system—point, line, distance and so on—were held to refer to things which exist in the real world or at any rate are approximately copied by real things: and the axioms of the geometry are supposed to be true statements about these real things. They were also supposed to be self-evidently true, with the exception of the axiom of parallels; it was hoped for centuries that it could be shown that to deny the axiom of parallels would lead one to a contradiction with the other axioms, but eventually geometries were constructed in which the axiom of parallels was denied, for example, Lobachevskian geometry, in which the existence of an infinite number of lines through a given point parallel to any given line is asserted. What is more, these systems were proved to be free from contradiction.

One way in which this consistency, or freedom from contradiction, of Lobachevskian geometry was proved is the following. Draw a circle Γ in the Euclidean plane. Agree that whenever the words 'point' and 'line' occur in Lobachevskian geometry we shall mean by them point inside Γ, part of line inside Γ, respectively; by the 'distance PQ' in the Lobachevskian geometry, we shall mean log AP.BQ./AQ.BP, where A, B are the points in which PQ meets Γ, and AP, etc., are the Euclidean distances. Angles are to be defined similarly, as $\frac{1}{2}i$ times the logarithm of the cross-ratio of the range formed by the lines of the angle and the tangents to Γ from their intersection. It is quite easy to check that the simplest of the ordinary axioms of Euclidean geometry hold; for instance, that if P, Q, R are collinear, 'distance PR'='distance PQ'+'distance QR'. Yet through any point there are an infinite number of lines which do not meet a line not through that point.

We have thus found a set of objects, constructed in terms of concepts of Euclidean geometry, which obey non-Euclidean geometry. A set of objects which obeys the axioms of a mathematical system is called a *model* for that system; we have here a model for Lobachevskian geometry.

The important conclusion we can draw from the existence of a model is that the system does not contain contradictions, that is, it is consistent. It is

vital that a mathematical system be consistent; for if one can prove two contradictory statements in any logical system, one can prove any statement whatever, and in an inconsistent system any statement whatever is a theorem, so that the system is possibly useless.

From the classical point of view, the validity of Euclidean or non-Euclidean geometry was thought to depend on their truth for points or lines of real space; from the modern point of view, this is a question of physics, not of mathematics, and the fact that non-Euclidean geometry is supposed by relativity theory to hold in the real world in no way affects its mathematical status, though it certainly increases its interest and gives an incentive for studying it. Even without this, however, the study of Lobachevskian geometry would be more than an idle game; for example, it is important in the theory of functions of a complex variable. Validity of a mathematical system in the modern sense is a question of its consistency; if a geometrical system is consistent, it is a worth-while object of mathematical study, and, experience has shown, it generally has application in subjects where the 'points' of the geometry may be entities far removed in their nature from our intuitive idea of the points of space.

To prove that non-Euclidean geometry is consistent we have used a model based on Euclidean geometry, and in so doing implicitly assume the consistency of Euclidean geometry. We can go on to construct a model for Euclidean geometry in terms of the real numbers, interpreting points to mean ordered sets of real numbers, more or less as in analytical geometry. This gives a proof of the consistency of Euclidean geometry, but it assumes the consistency of the theory of the real numbers. For the real numbers, we can construct a model in terms of the theory of sets; this is what Frege and Russell aimed to do, and which they called, rather misleadingly, the reduction of mathematics to logic. Unfortunately, this last stage ran into difficulties, for serious inconsistencies, the antinomies of set theory, were discovered, and the difficulties they raised have not quite been resolved. Axiom systems have indeed been constructed which avoid the known antinomies, but we can have no proof that mathematics as whole is consistent.

Let us now assess the degree of truth in the theories that mathematics consists of tautologies or that it is solely a matter of definition. These theories are frequently coupled, though they are in fact distinct. They will be found, for example, in Ayer's *Language, Truth and Logic*, where they are supported by the picturesque, if scarcely verifiable, statement that 'A being whose intellect was infinitely powerful would take no interest in logic or mathematics. For he would be able to see at a glance everything that his definitions implied, and, accordingly, could never learn anything from logical inference which he was not fully conscious of already.' This couples the definition theory of mathematics with the theory that, within a given set of definitions—and axioms are regarded here as definitions—the truth or falsehood of any statement can be decided by a purely mechanical process, say, that a computer could be built which, on having fed to it the axioms of mathematics, could settle the truth of any theorem, given enough time; for a computer with indefinite time is the nearest we can get in this world to Ayer's being with infinite intelligence; and, if his philosophy needs divine help to save it, we are not better off in the next world, if theology is correct in holding that divine omniscience extends to the physical world as well as to mathematics.

The tautology theory of mathematics is essentially a result of generalisation from too special cases. It is based firstly on the obvious fact that it is true of elementary arithmetic; the truth of an arithmetical calculation, however complicated, can be checked by a purely mechanical decision process. Secondly, it is based on the fact that the same is true for elementary logic, the propositional calculus. Any of the theorems of this calculus, which is to be found, for example, at the beginning of *Principia Mathematica*, can be checked by a purely mechanical process. It was this which led Wittgenstein to put forward the tautology theory of mathematics; for he accepted Russell's claim to have reduced mathematics to logic, and equated logic with the elementary propositional calculus. However, it has been proved that no mechanical decision process is possible even for the whole of mathematical logic, let alone for all of mathematics. The tautology theory should, therefore, be regarded as one which applies to some relatively trivial parts of mathematics, but not to the more interesting parts and certainly not to the whole subject.

The definition theory has more truth to it; indeed, it has a validity for any section of mathematics. It is quite correct to say that the undefined terms in any mathematical system have the properties assumed in the axioms as a matter of definition, and that any theorems of the system are true as a result of these definitions. A statement about points, lines and so on which is valid if these things occur in a model for Euclidean geometry may be false for a model of a non-Euclidean geometry.

However, it would be just as true to say that the formulae of chemistry are a matter of definition; for if we assigned the names of the elements in a different way we would get quite different chemical formulae. Nevertheless, a statement that chemistry is a matter of definition would ignore the fact that however the names are jumbled, for a chemical system to be valid there must be some way of assigning elements to the names which makes the formulae correct; to make the analogy clear, there must be some assignment of elements to names of elements which makes the actual behaviour of matter a model for the chemical system. In the same way, the assertion that mathematics is purely a matter of definition ignores the problem of the validity of mathematical systems. For particular systems, this validity can be established within mathematics, by constructing models for a given system in terms of another axiom system—say geometry in terms of the real numbers; but eventually we must come to a primary system of axioms, and if we are to have any sort of guarantee of validity for this it must be found outside mathematics.

What sort of guarantee can we have? This is a very difficult question, and it would be wrong to suggest that mathematics must be tied down to, or that it does imply, any one answer. Certainly there can be no absolute guarantee of the consistency of mathematics: any science is liable to error, and the progress of mathematics in the future may reveal unsuspected inconsistencies, as it has done in the past. However, this does not allow us to dismiss the whole problem of consistency; to do so would be to treat mathematics as a sort of game, like a chemical system with any random combination of elements allowed: and it would make the possibility of applying mathematics an insoluble problem. We cannot take the subject seriously without a conviction that any contradictions there may be are peripheral and remediable. Such a conviction cannot, again, be based solely on an appeal to empirical experience, since, for example, mathematics deals with sets of indefinitely large magnitude and with infinite sets, and these cannot, as such, be part of empirical experience. It is because of this that empiricist philosophers try to explain mathematics away, in the ways I have described. I do not wish to involve myself in metaphysical knots; but it seems reasonable to say that the source of our convictions about mathematics must arise from a correspondence between the terms of mathematical theories and some of the things which our minds either bring to or find in our experience of the external world, or create by generalisation, abstraction and extrapolation beyond experience. I shall leave this thorny subject and go on to discuss what it is that mathematics deals with.

The subject of any mathematical theory is a *mathematical structure*; and by a mathematical structure I mean a set of objects for which some defined relations exist between its elements, or between sets of its elements of even between sets of sets of elements.

Most of the mathematical structures we encounter are complex, in the sense that they are combinations of structures with fewer relations. Complex structures can be seen as being built up out of elementary structures: I am using the word elementary in the sense of logically simple, not the pedagogic sense. There are two main types of elementary structure in mathematics, which between them appear to cover all the cases which arise in modern mathematics:

(1) *Algebraic structures*, in which the defined relations are between finite numbers of elements.

(2) *Topological structures*, in which the relations are between pairs of sets, or between individual elements and sets or between individual elements and sets of sets.

I can best show what this means by first taking a familiar complex structure, the real numbers, and explaining the elementary structures which it involves. The real numbers have three elementary algebraic structures:

(i) The structure of addition: three numbers a, b, c may be related by the rule $a+b=c$.

(ii) The structure of multiplication: three numbers may be related by $ab=c$.

(iii) The structure of order: two numbers a, b may be related by $a>b$.

These structures are linked by a variety of laws: thus

A. $a+b=b+a$ $\quad a+(b+c)=(a+b)+c$
$ab=ba$ $\quad a(bc)=(ab)c$
$a(b+c)=ab+ac$

There is an element 0, such that $a+0=a$ for all a. For any a there is an element $-a$, such that $a+(-a)=0$.

B. There is an element 1 such that $a.1=a$ for all a.

C. For each $a=0$ there is an element b such that $ab=1$.

In addition, the real numbers have a topological structure, which is what is involved whenever we talk about such matters as limits, convergence and so on. The typical relationship which describes the topology of the real numbers is that of neighbourhood:

A neighbourhood of a real number a is any set which includes an interval with a as midpoint.

If we consider geometry, again, we are once more dealing with a complex structure. The structures involved in geometry are mostly algebraic: they involve finite sets of objects, in relations such as incidence—a point being on a plane, a plane passing through a line. It is only when we come to consider differential properties—tangency, curvature of curves and surfaces—that topological structures are brought in.

The characteristic differences between classical mathematics—say that of a century ago—and that of modern mathematics is that classical mathematics dealt pre-eminently with complex structures, modern mathematics with less complex ones.

The reason for this is very practical. If we discuss a complex structure that structure may be so tightly specified by the numerous relations which define it that, roughly speaking, only one example of the structure exists: or, to be more exact, if we have two sets of objects which both have that structure, then they are exact pictures of one another, as one Euclidean plane is an exact picture of the other: the objects in the two sets can be made to correspond univocally so that all the relations are transferred by the correspondence. For instance, anything which obeys the sets of laws A, B, C, and in addition has the order structure of the real numbers is an exact picture, in this sense, of the real numbers. On the other hand, a less complex structure may have as examples vastly different things. Thus, any set of objects which obeys the laws A and B is called a commutative ring with unit. Any deductions we make which are based exclusively on A and B will hold for any such ring. Now, the polynomials form such a ring: so do the functions of a real variable; and consequently if we restrict ourselves to the axioms for a ring, our conclusions will be valid for a wide variety of mathematical objects, whereas conclusions based on the entire set of axioms for the real numbers cannot be guaranteed to hold for any structures other than the real numbers.

The word 'space' has thus acquired an enormous extension of meaning in mathematics. On the one hand, it has been used for anything which has the algebraic properties of the vectors of Euclidean space: the possibility of addition and multiplication by numbers. On the other, it is used for any set of objects which has topological properties, no matter how different those may be from the topology of Euclidean space. These two extensions combine in a very fruitful manner in the theory of function spaces: for functions can be added like vectors, if $f(x)$ and $g(x)$ are real functions so are $kf(x)+lg(x)$ for any real numbers k and l, and they can be assigned topological properties; we can even define a distance

$$\text{distance from } f \text{ to } g=\left\{\int|f(x)-g(x)|^2dx\right\}^{1/2}$$

A space of functions with this definition of distance has properties very similar with those of Euclidean space: it differs only in having an infinite number of dimensions. Consequently, we can transfer many ideas gained in experience of Euclidean space to such function spaces, and so are led to discover properties of functions, by thinking of functions as points of a space.

This method has its difficulties and dangers, of which the greatest is that we may be misled into transferring statements which are only true in Euclidean space to a functional space. It is therefore necessary to make sure that our arguments are based solely on our axioms, and that we do not introduce tacitly assumptions brought over

from Euclidean space. Rigour of argument is therefore highly important in this sort of mathematics; its role is to ensure that anything which we assert to follow from the axioms of a structure holds for all structures obeying those axioms and not merely for those familiar to our intuition.

I would like to illustrate the variety of things which can share a mathematical structure by discussing the example of a Boolean ring. Now a ring means any set of objects which obeys the axioms A, B, C. A Boolean ring is one which in addition satisfies the axioms:

$$a+a=0, \quad a^2=a, \text{ for all elements } a$$

The simplest structure which obeys the laws of a Boolean ring consists of just two objects, 0 and 1, with the usual law of multiplication and the usual law of addition save that $1+1=0$. An example of such a ring is got by taking 0 to mean the set of all even numbers, 1 to mean the set of all odd numbers: then $1+1=0$ means that the sum of any two odd numbers is even. More complicated examples are:

(1) *Propositional logic.* In this, the elements are propositions. If a and b are propositions, ab is the proposition 'a and b', $a+b$ is the proposition 'exactly one of a, b is true'. 0 stands for a proposition which is always false, 1 for a proposition which is always true. Clearly $a+a$ is always false, so $a+a=0$; a^2, a and a, is the same as a.

(2) *The subsets of a set.* Here 0 is the empty set, 1 is the whole set, ab is the set of objects common to a and b, $a+b$ the set of objects which is in one but not both of a and b.

(3) *Electrical switching circuits.* Consider any electrical circuits involving switches. The symbols of the theory stand for partial circuits. 0 means a circuit which is always broken, 1 a circuit which is always connected. If two switches are so arranged as to be always on or off together, they are both denoted by the same symbol; if they are arranged so that they are always opposed, then if one is denoted by a the other is denoted by $1+a$. If two circuits a, b are in series the joint circuit is denoted by ab; if in parallel, by $a+b+ab$. Then the laws of Boolean algebra are obeyed; any circuit can be given a symbol in terms of the symbols for the switches in it, and from this symbol we can work out how the circuit behaves.

To sum up: the role of mathematics is to discover and investigate structures which arise in our theoretical treatment of physical experience and in mathematics itself. Mathematical training should be directed to building up an ability to form an intuitive grasp of such structures—intuitions of geometric space, of number, of algebraic relations and so on; the mechanical side of mathematics, the purely linguistic side, that is the ability to read notation, are important, but should not be stressed at the expense of understanding.

THE LANGUAGE OF THE GENES*

By Dr. GEORGE W. BEADLE *Professor of Biology, California Institute of Biology*

Our methods of communication with our fellow men take many forms. We share with other animals the ability to transmit information by such diverse means as the posture of our bodies; by the movements of our eyes, head, arms and hands; and by our utterances of non-specific sounds. But we go far beyond any other species on earth in that we have evolved sophisticated forms of pictorial representation, elaborate spoken and written languages, ingenious methods of recording music and language on discs, on magnetic tape and in a variety of other kinds of code.

Our remarkable skills in communication depend of course on our highly developed nervous systems with their provisions for transmitting information from various receptors to the central brain where it can be stored, integrated and reproduced. In this way it has been possible for us as a species to acquire knowledge and understanding in a cumulative way. Present-day cultures, including religion, art, music, language, literature, technology and science are the result. All these we pass on from one generation to the next, adding to the sum with each such passage.

In this lecture I am going to talk about the transmission of biological directions for development and function from generation to generation in organisms as varied as submicroscopic viruses and man.

The Egg Cell

Let me begin by reminding you that each of us begins development as a small almost microscopic single cell, the fertilised egg. It is about $\frac{1}{300}$ of an inch in diameter—about one-tenth the diameter of the head of a pin. A human egg does not look very different from the egg of a rabbit, a guinea pig, or a chimpanzee. In fact is is not too unlike the egg cell from which spinach plant develops. Yet each of these cells obviously 'knows' what its potential future is, for gross mistakes do not occur. The egg of a rabbit never gives rise to a guinea pig. Clearly the egg cell must contain information that says what it is going to do. A human egg carries specifications for growing into a person—not just any person but a very specific and truly unique one.

It is these specifications about which I wish to speak. I'll begin by posing five questions: First, how are these specifications or directions transmitted from one generation to the next? Second, how are they 'written', that is, what is the 'language' of heredity? Third, how are they replicated or 'reprinted' as they must be with each of the many cell divisions that intervene between the egg of one generation and the egg and sperm cells of the next? Fourth, how are these directions 'translated' during development? How are they used in the transformation of a tiny spherical egg into one of us? Finally, do errors or changes in the directions ever occur and, if so, what are the results?

Although it is by no means possible to give complete answers to these questions, we can come much closer to doing so than we could a few years ago. But before I go ahead, let me narrow my task considerably. The egg cell of an animal is, of course, complex, despite its small size. It consists of cell membranes enclosing cytoplasm, which constitutes the bulk of the cell, and a centrally located nucleus. I am going to confine my remarks largely to the nucleus. In doing this I do not wish to leave the impression that I believe the cytoplasm to be unimportant. The fact is in all cellular

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forms it is indispensable. It is endowed with highly specific properties and in a real sense carries essential hereditary information. This is clear from the experiments of the kind Dr. Fischberg of Oxford University, Prof. John Moore of Columbia University and several other embryologists have made in which the nucleus of the egg of one species of animal is replaced with that of another. Thus, in the two species of frogs, *Rana pipiens* and *R. sylvatica*, the nucleus of the fertilised egg of one species can be removed and replaced by that of the other (Moore, 1958). Whichever way the switch is made, the egg fails to develop, although the comparable transfer in which donor and recipient are of the same species leads to normal development. *Rana pipiens* cytoplasm is not compatible with a *R. sylvatica* nucleus and vice versa. This is only one of several lines of evidence indicating that the egg cytoplasm has specific properties that cannot be easily modified by the nucleus.

In confining my attention largely to the nucleus, I likewise do not wish to belittle the role of environmental factors. They, too, are absolutely necessary. For a human egg cell to develop into a person, for example, a highly specific physical and chemical environment must be maintained, especially in the early stages of foetal development. Raw material of the proper kind must be available in the right amounts and at the right times. Before and after birth the nervous system is being indelibly impressed with information. Especially after birth the information that is fed into the nervous system in massive amounts plays a large and important role in determining what we are. It includes a large input of cultural inheritance.

The Nucleus and Genes

Getting back to the nucleus, there is an impressive body of evidence showing that in it is contained a very large part of the primary biological information that directs development and function. Mendel demonstrated in his garden peas that this information is particulate. Unfortunately, he was far ahead of his time and was quite unable to convince such persons as the German botanist Nägeli that what he found should be taken seriously. Had Darwin known of his work, the history of science might have been profoundly changed.

Mendel postulated the units of heredity that we now call genes. He did not know they were in the nucleus of the cell or that they were carried in chromosomes. But he did know that they determine whether pea seeds will be round or wrinkled, whether green or yellow, whether the flowers will be purple or white, whether the pea plant will be tall or short, and so on. He had a remarkable understanding about how genes are transmitted from one generation to the next. Although modified in important ways, his laws of inheritance still hold as first approximations to the ways of nature in communicating specifications from parent to offspring.

We now know that the most basic features of the process of transmission of biological directions for development are common to viruses, bacteria, algae, protozoa, higher plants, multicellular animals and man. Let me give you an example in man. About seven out of every ten persons find the chemical substance phenylthiourea most unpleasantly bitter. The remaining three find it essentially tasteless. The two classes of people differ in the hereditary specifications. Individuals who taste it carry specifications in their cells that somehow say, 'I can now taste phenylthiourea', whereas those who do not taste this substance carry the alternative form of this message, 'I cannot taste phenylthiourea'. This message, in its two forms, is one unit of inheritance—a gene. Each fertilised egg, and all the cells descended from it contains two representatives of this message, one from the mother, via the egg, and one from the father, via the sperm. There are, therefore, four possible types of persons with respect to this particular bit of specification, viz.:

From the mother	*From the father*
1. Taste	Taste
2. Taste	Not taste
3. Not taste	Taste
4. Not taste	Not taste

The first is a pure taster. The next two are alike in having one message of each kind. They are 'hybrid' for this message. They taste, which is a way of saying the positive taster form of the message is *dominant* to the non-taster form, or, vice versa, that the negative form is recessive.

When sperms or eggs are produced by individuals of these types, each carries one or the other of the two messages, either the maternal *or* the

paternal one. Thus from any pair of parents it is easy to predict statistically the types of offspring, just as Mendel did with his peas.

How many such units or genes are contained in the nucleus of a human egg cell? We do not know with any degree of certainty. But we estimate that it is probably more than 10,000 kinds and less than 1,000,000, each present in duplicate except for sex-linked genes which are for the most part present singly in the male. What do these genes specify? Many characteristics: eye colour, hair colour, hair form, skin colour, and hundreds of other characters by which the species may differ.

You may remark, as many biologists did in the early part of the century just after Mendel's work was rediscovered and while the young science of genetics was struggling for recognition, that these are all trivial characters. So they are, as are most of the characteristics responsible for the uniqueness of normal individuals. But we now have abundant evidence that most genes carry information of vital importance. Thus two genes in man carry the instructions for making the haemoglobin molecules that play such an essential role in carrying oxygen and carbon dioxide. Haemoglobin is *not* trivial.

Soon after the rediscovery of Mendel's classical paper, it was suspected that genes were carried in chromosomes. The clinching proof came in 1915 from the laboratory of the late Thomas Hunt Morgan. His student, Calvin Bridges, showed that errors in transmission of genes are exactly paralleled by errors in chromosome behaviour.

DNA as Genetic Material

Chromosomes were known to be made up largely of protein and nucleic acid, the latter of the deoxyribose type. Deoxyribonucleic acid has now become widely known as DNA. Are the genes protein of DNA—or possibly both? At first their specifications were thought to reside in protein, for chemists knew that proteins are long polymer molecules consisting of linear sequences of amino-acid building blocks of some twenty kinds. Since there are obviously almost unlimited possibilities in proportions and sequences of amino acids, it was easy to believe that the gene was a kind of coded message in protein. DNA, on the other hand, was believed by many to be a rather monotonous polymer built of four kinds of nucleotide units arranged in segments of four that were repeated many fold. If this were its structure, there would clearly be little opportunity for specificity; therefore it was not considered a serious candidate for the role of primary genetic material.

A series of investigations on pneumococcal bacteria, beginning in 1928 and leading up to the classical paper of Avery, MacLeod and McCarty (1944), severely shook the faith in protein as the basic stuff of heredity. It became clear that the type of polysaccharide capsule produced by a pneumococcal strain could be altered experimentally by treating it with pure DNA from another strain. Thus DNA from a type III pneumococcus could cause a type II recipient cell to be transformed permanently into type III, and henceforth to produce DNA specifying type III polysaccharide. The experimental procedure by which this is accomplished is not quite as simple as the above account implies. Nevertheless it appeared that polysaccharide-specifying DNA from the donor strain might be entering the recipient and somehow replacing its homologous DNA. There were, however, alternative interpretations, which, though less straightforward, continued to be preferred by many geneticists and biochemists.

By 1953 more direct evidence had come from another source. By then the life-cycles of certain bacterial viruses—bacteriophage—had been worked out and sufficient genetic work done on them to make it clear that like higher organisms they exhibited particulate inheritance. In other words, these viruses, too, have genes.

Bacterial viruses consist largely of protein coats containing cores of DNA. Electron microscopy suggested that when a bacterial cell is infected by a virus particle, its coat does not enter the host cell. The matter was most elegantly settled by the use of radioactive tracers. Hershey and Chase (1952) infected bacteria with viruses whose protein coats were labelled with sulphur-35, a radioactive isotope. The labelling was done by growing a crop of viruses on bacteria that in turn had been grown on a medium containing radioactive sulphur in the form of sulphate. After infection, the protein coats were removed from the bacterial hosts by shearing them off in a high speed blender. Separated by centrifugation, the virus coats and infected host cells could be separately examined for presence of radioactive sulphur. Almost all of it was found in

the virus coats that did not enter host cells. Since proteins contain sulphur while DNA does not, this result suggests that only DNA enters the host on infection. Experiments in which DNA was labelled with radioactive phosphorus-32 led to the same conclusion. Now the coats were largely unlabelled after infection had occurred, while the host cells contained most of the radioactivity. Since DNA contains phosphorus—one atom per nucleotide—and protein does not, it is clear that DNA and not much else enters the host cell. Since viruses have genes and only DNA enters the host cell, the viral genes must be DNA. Actually a small amount of protein does enter with the DNA, but labelling experiments in which the radioactivity entering a host cell in protein or DNA is followed to the next viral generation show that it is the DNA, not the small amount of protein, that is responsible for the transfer of genetic information from one generation of viruses to the next.

What about higher organisms—spinach plants and man? Are there primary genetic specifications likewise written in DNA? The evidence is not conclusive but since the most conservative hypothesis assumes they are, we proceed on that assumption until evidence to the contrary comes forth.

Structure of DNA

What is the structure of DNA that enables it to carry hereditary information? A tremendous step was taken toward answering this question in 1953 by a young American biologist, James D. Watson, and the English chemist, Francis H. C. Crick, working together at Cambridge University. Making use of the information then available about DNA—nucleotide composition of DNA of various sources, X-ray diffraction observations of M. H. F. Wilkins and associates at King's College, London, general knowledge of the structural arrangements of atoms in nucleotide components, etc.—they succeeded in constructing a molecular model of DNA that seemed to satisfy essentially all requirements (Watson and Crick, 1953). Now, some seven years later, it is generally agreed that the Watson-Crick structure is essentially correct for the native DNAs of a number of organisms. It is now clear that their achievement is outstanding in modern-day biology. This is so because their model goes so far in suggesting plausible answers to the questions posed at the beginning of this lecture.

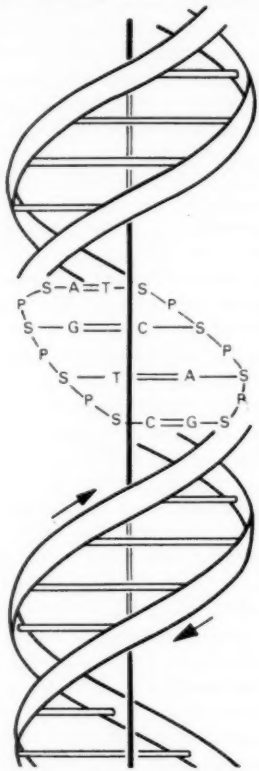

Fig. 1.—The Watson-Crick structure of DNA. Deoxyribose sugar, phosphate, adenine, thymine, cytosine and guanine represented by S, P, A, T, C and G. Hydrogen bonding shown by horizontal double lines. (*Redrawn from Watson and Crick* (1953).)

According to this model, DNA consists of a pair of antiparallel polynucleotide chains wound helically around a common axis and cross-linked through specific hydrogen bonding between purine and pyrimidine bases. This is illustrated schematically in Fig. 1. Letting A, T, C, and G represent the four nucleotides characterised by adenine, thymine, cytosine and guanine, a four-unit segment of DNA can be represented in two dimensions as follows:

A–T–C–G
T–A–G–C

Paired dots represent hydrogen bonds. As indicated by arrows in Fig. 1, the two chains of the DNA molecule run in opposite directions. This is determined by the orientations of nucleotides in the two chains.

Information in DNA

Genetic information must somehow be determined by sequence of nucleotides. Since only A:T and C:G nucleotide pairs are possible in the normal structure, the two chains obviously carry complementary information. As we shall see this is of special significance in hypotheses of DNA replication.

One can think of information being carried either as a sequence of nucleotide pairs in the double molecule or as nucleotide sequences in the two single chain components.

How much DNA is in a single human cell? It is estimated that the total DNA of the 46 chromosomes of a fertilised human egg contains something like 5,000,000,000 nucleotide pairs. Since the genetic material is carried in duplicate in such a cell, one complete set of information is written in sequence of some 2,500,000,000 such pairs.

Prof. Crick has estimated that this amount of DNA is sufficient to encode the contents of some 500 large library volumes. This is another way of saying that the genetic specifications for producing a person from an egg cell, given a proper environment, adequate food of the right kind, etc., might be written in English in this number of volumes.

What about the physical size of DNA molecules? The diameter of the double helix is 20 Ångström units. The base pairs are spaced at 3·4 Å intervals. Thus a continuous linear double helix of the 5,000,000,000 base pairs of a single human egg would be somewhat more than 5 ft. in length—only slightly less than the height of an average person. This is a convenient way to remember the amount of DNA in a single human cell. If the strands were packed side by side in a monolayer on the head of a pin 1 mm. in diameter, this amount of DNA would cover less than $\frac{1}{200}$ of the surface.

Replication of DNA

The Watson-Crick structure immediately suggested how DNA molecules might reproduce by separation of the double structure into single chains followed by synthesis of new partners against each of the old chains. Since the two originals are complementary, each carries the information necessary to direct the synthesis of its partner. It is presumed that single chains serve as templates against which free nucleotides are properly ordered by specific hydrogen pairing. Assuming the old chains to remain intact this process can be schematically represented in the manner shown in Fig. 2. Just how the problems of separation of paired chains helically coiled around a common axis is solved is not known. The forces required to 'untwist' the double helix would not be great if it were to rotate around its axis in the manner of an automobile speedometer cable.

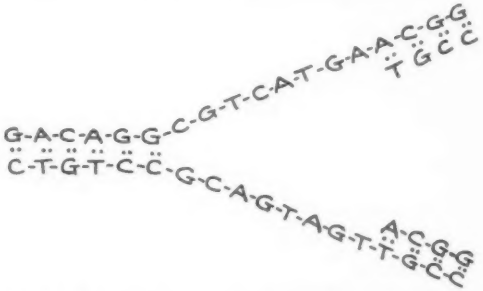

Fig. 2. Schematic representation of DNA replication. At left, original double chain; at right, new chains being synthesized against old chains as templates.

Is there any evidence that DNA replication in fact occurs in this way? Yes, two kinds of evidence indicate that it does.

One of these depends on labelling old and new chains so that they can be distinguished. This can and has been done with radioactive phosphorus-32, but there are difficulties in this method that have not been overcome in an entirely satisfactory manner. A second method of labelling involves the use of the stable heavy isotope of nitrogen, N^{15}. Bacteria grown on a culture medium containing only N^{15} eventually become fully labelled with this isotope. Since there are seven or eight nitrogen atoms per pair of nucleotides of molecular weight approximately 700, replacing all N^{14} with N^{15} increases the weight a bit over one per cent. Since the size does not change, the density increases by a corresponding amount. 'Heavy' DNA molecules

can be separated from the light variety in an analytical ultracentrifuge.

The method for doing this was first developed by Meselson, Stahl and Vinograd (1957) and consists in centrifuging DNA in a cesium chloride solution of proper density. The cesium chloride molecules are thrown down in a high centrifugal field, but, being small, they diffuse sufficiently to establish an equilibrium density gradient in the centrifuge cell. If the range of density so established includes that of DNA, the DNA molecules in solution will form a band at a level exactly corresponding to their buoyant density. Being large they diffuse only slowly and hence form a narrow band, the position of which is easily established by means of an ultraviolet optical system. A mixture of N^{15} and N^{14} DNA molecules form two cleanly separated bands.

This method makes possible the following elegant experiment first carried out by Meselson and Stahl (1958). Bacteria are grown on N^{15} medium until equilibrated, that is, until they become uniformly heavy. The bacteria are then transferred to a medium containing only nitrogen of atomic weight 14. After one cell generation, as determined by doubling of the total population, all DNA molecules should have one heavy old chain and one light new complement. That is, they should be 'hybrid' and hence intermediate in density between heavy and light DNA. They are. In a second round of replication—which doubles the population again—heavy and light chains should separate and each them direct synthesis of a light complement. Hence, half the DNA molecules after exactly two cell divisions should be hybrid and half light. Again they are. (Figs. 3 and 4.)

If a population of hybrid DNA molecules—

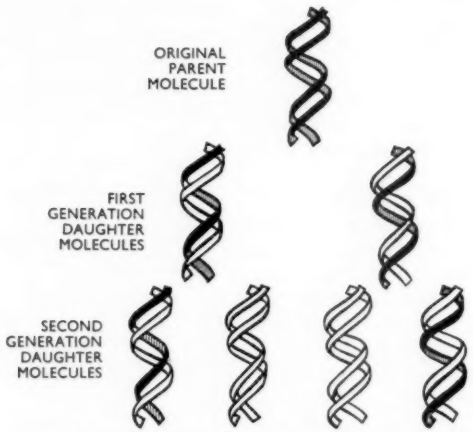

Fig. 3.—Representation of Meselson-Stahl experiments. Nitrogen-15 labelled helices black, nitrogen-14 helices white.

present after one replication of heavy molecules in an N^{14} medium—are heated under the right conditions, molecules about half the molecular weight are found and they are light and heavy in equal numbers. The evidence is fairly convincing that these are single chains of DNA.

This experiment does not prove that the Watson-Crick hypothesis of DNA replication is correct but it strongly suggests it. A perverse nature might have devised another way of giving the observed result.

The Kornberg System

An even more dramatic way of investigating the mechanism of DNA replication is that devised by Arthur Kornberg and his co-workers (1959). In a

suitable buffer solution containing magnesium ions, the four nucleotides of DNA as triphosphates, and a DNA polymerising enzyme, DNA is rapidly synthesised if primer DNA molecules are added. Single stranded DNA, obtained by heating native DNA, is much more effective as a primer than is carefully prepared native material. Something like a twentyfold increase in DNA over that added as primer has been obtained.

That the primer is copied is indicated by the fact that the base composition of the product is like that of primer. DNAs from different sources may have quite different ratios of A:T to C:G base pairs, and it is therefore possible to determine whether the ratio of the primer is reproduced in the product.

Without primer, DNA is spontaneously synthesised in the Kornberg system after a lag of two to four hours. But unlike natural DNA, this spontaneously synthesised material contains only A:T base pairs. The As and Ts alternating in sequence in each of the two chains as follows:

—A—T—A—T—A—T—
‖ ‖ ‖ ‖ ‖ ‖
—T—A—T—A—T—A—

If this A:T copolymer is now used as a primer in a fresh system, more A:T polymer is formed without a lag period. C and G nucleotides are excluded although present in abundance in the system. Here too it appears that the primer is copied as postulated.

Again, the agreement between hypothesis and the facts observed in the Kornberg *in vivo* synthesis of DNA does not prove the hypothesis. But it enormously strengthens the case.

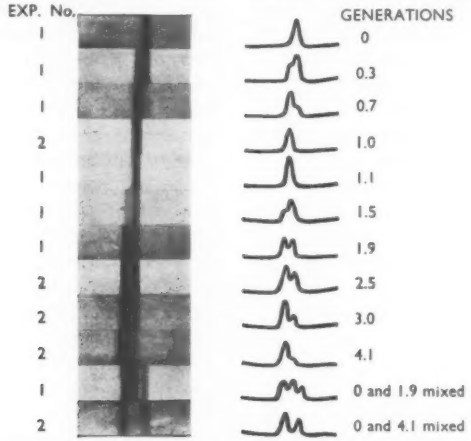

Fig. 4.—Results of the Meselson-Stahl experiment. At left, banding of DNA from bacteria originally labelled with N^{15} and allowed to multiply in an N^{14} medium for the indicated number of generations. At right, density measurements of ultraviolet absorption bands showing distribution of DNA molecules. Density increases from left to right. (*From Meselson & Stahl* (1958).)

Use of DNA Information

How is information in the form of DNA made use of in the development of an organism like man? This is clearly a question of the most fundamental importance to biology. At the same time it is an enormously difficult one and we are a long way from knowing the complete answer.

All living systems contain DNA (or in some viruses a related form of nucleic acid, ribonucleic acid, called RNA) and protein. In cellular forms the proteins are of many kinds. We know that many genes, perhaps all, are somehow concerned with synthesis of specific proteins. Many of these serve as organic catalysts—enzymes—or as components of these catalysts. Enzymes accelerate vital

reactions that would otherwise proceed at rates too low to sustain life. In cellular organisms there are thousands of kinds of enzymes, each owing its specificity to a particular protein. We can therefore narrow the problem of gene action, at least in some cases, to that of protein synthesis.

An hypothesis at present widely used as a working basis visualises the process of protein synthesis in the following way: for each protein potentially capable of being formed, there is in the nucleus a specific segment of DNA that carries the information by which the twenty kinds of amino acid sub-units in that protein are properly ordered during its synthesis. Take human haemoglobin as an example. Each molecule of this vital oxygen-carrying red protein consists of four protein chains and an equal number of heme groups each containing an atom of iron. The protein chains are of two kinds, called alpha and beta chains. There are two of each, the members of a pair being identical and each made up of about 150 amino-acid units arranged in a precisely determined sequence. For each of the two kinds of protein chains, there is presumed—with some evidence—to be a gene consisting of a segment of DNA. This segment is, by the definition I shall use, a gene. It may be something of the order of 1000 nucleotide pairs in length.

How is the information in the gene for the alpha haemoglobin chain made use of? The hypothesis assumes the following sequence of events: from the gene in the nucleus, information is transferred to RNA, presumably by the DNA somehow acting as a template in the ordering of the four kinds of ribose nucleotides in RNA. This informational RNA then moves from the nucleus to the cytoplasm of the young red blood cell—before it loses its nucleus. There it is incorporated into microsomes, which are sub-microscopic bodies made of structural protein and structural RNA. Once in microsomes, informational RNA molecules serve as templates against which amino-acids are arranged in proper order to make alpha haemoglobin protein chains.

Prior to this the amino-acids are activated and attached to small carrier segments of RNA, each specific for its own amino-acid. Thus for each of the twenty amino-acids there is a corresponding carrier RNA segment. Carrier RNA molecules are somehow coded to specific sites on the informational RNA in the microsome. In this way each amino-acid is carried to its proper position on the template. They are then joined through peptide linkages to form alpha chains and are released from the template and microsome. Whether association of alpha and beta chains with their hemes, and with each other, occurs in the microsome or outside is not known.

Not all proteins for which genetic directions are available in the nucleus are synthesised in any one cell. There are ingenious control mechanisms in operation which determine whether the information in a given gene will be used and, if so, when and for how long. In some cases it is clear that the presence or absence of substrate determines whether a given enzyme will be synthesised. In this way it is assumed that enzymes are not made in quantity when there are no substrates on which they can work. Through studies on such control mechanisms we are beginning to understand how it is that cells with identical genetic information in their nuclei may do quite different things, depending on their environmental context or on their previous history.

There are now known many instances in a variety of organisms in which specific protein variation is known to be related to particular genes. I have already referred to haemoglobin protein in man. Similar situations are known in viruses, bacteria, algae, fungi, insects, higher plants, mammals, etc. (Beadle, 1960). The haemoglobin case in man is interesting in that it is known that gene changes may result in substitution of a single amino-acid in a chain of 150 units. Thus sickle cell haemoglobin, synthesised under the direction of a modified form of the gene in control of the beta protein chain, differs from normal haemoglobin in that a single glutamic acid unit in the chain is replaced by a valine. In the presence of a third form of this same gene the same glutanic acid unit is replaced by the amino-acid lysine. In all, about a dozen modifications of human haemoglobin are known, many of them investigated genetically.

Another example in man is found in the genetic disease galactosaemia. Here is a specific enzyme, galactose-1-phosphate uridyl transferase, essential for the conversion of galactose into a usable form, which is partially or wholly inactive. The enzyme defect is referable to a gene change.

In bacteria, fungi and other micro-organisms

correlations between gene change and specific protein modification are much easier to detect than they are in man with his several obvious disadvantages for biochemical and genetic investigations. As a reult there are dozens of examples known in such forms as *Escherichia*, *Salmonella* and *Neurospora*.

Mutation

In terms of DNA structure gene mutation is believed to be the result of alterations in nucleotide sequence. Many mutations are thought to be the result of errors in DNA replication. In their original paper on DNA structure, Watson and Crick pointed out that if at the precise moment of partner selection a purine or pyrimidine were to exist in an improbable tautomeric form, it might form hydrogen bonds with a 'wrong' nucleotide. At the next round of replication such a 'wrong' nucleotide would direct that its own complementary nucleotide be inserted in the paired chain. Thus one of the two daughter DNA molecules would differ from its sister in one nucleotide pair. Its informational content would be modified accordingly.

Experimentally mutations can be increased in frequency in a number of ways. High-energy radiations—ultraviolet, X-rays, etc.—are effective in doing this. Transmutation of artificially incorporated radioactive isotopes such as phosphorus-32 is known to produce mutations. Since radioactive isotopes occur naturally in low frequencies, they are no doubt responsible for a small fraction of spontaneously produced mutations.

Many chemical substances are known to be mutagenic. Perhaps the one best known from the standpoint of mechanism of action is nitrous acid. This specifically oxidises amino groups. In this way it may chemically change a natural DNA pyrimidine or purine in such a way that its hydrogen bonding specificity is modified. The mutagenic properties have been especially well studied in a tobacco mosaic virus, an RNA virus. Here the natural pyrimidine, cytosine is converted to uracil, which is also a natural occurring pyrimidine in RNA. Adenine is oxidised to hypoxanthine, the latter not a normal constituent of RNA. In a similar way guanine is changed to xanthine. It appears that the oxidation of any one of 3000 of the 6000 nucleotides in a tobacco mosaic virus particle results in an inactivating mutation.

The purine and pyrimidine analogues, 2-aminopurine and 5-bromouracil, produce mutations, presumably by being incorporated in replicating DNA in place of their natural counterparts and thereby leading to errors in complement selection. Since these analogues presumably replace their natural counterparts, purine for purine and pyrimidine for pyrimidine, it might be expected that they would be effective in reversing the mutations they induce. In a special class of bacterial virus mutants, investigated by Ernst Freese, this seems to be the case, whereas other classes of mutants, for example those induced by proflavine, are not so reversed by base analogues. It is presumed that the latter brings about replacement of purine by pyrimidine and vice versa. Investigations of this kind offer the hope of giving us a deeper understanding of the mutation process than we now have.

Fine Structure of Genes

If, as I have suggested, genes as functional genetic units of DNA are hundreds or thousands of base pairs long, it ought to be possible experimentally to demonstrate multiple mutational sites within a single such unit. Furthermore these should be arranged linearly within a unit. So called fine-structure studies on genes of bacterial viruses, bacteria, fungi and other organisms show that this is indeed the case (Beadle, 1960). Clearly the unit of mutation is much smaller than the unit of function, for such sites within a functional unit undergo recombination in much the same was as do separate genes within a chromosome. On the basis of frequencies of such recombination it is possible to construct intragenic maps of mutational sites and thus to show that they are linearly arranged. The shortest distances that can be measured by such recombination are not far from those that are calculated to exist between adjacent nucleotides in DNA.

The Coding Problem

How are sequences of nucleotides in DNA related to amino-acid sequences in proteins? DNA

and protein can be thought of as four- and twenty-symbol systems. If they are both equivalent to simple linear codes, it is clear that it requires at least three nucleotides to specify an amino-acid, for the maximum number of two-letter words is only sixteen. Several possible coding systems have been investigated but so far the problem has not been solved (Levinthal, 1959). Perhaps it will not be until nucleotide sequences in a gene can be compared with amino-acid sequences in the protein specified by that gene. As you know, complete amino-acid sequences have been worked out for only a very few proteins and unfortunately these are from organisms that are far from ideal for genetic study. There are now investigations under way in many laboratories designed to correlate genetic fine structure with protein fine structure. Virus proteins and bacterial enzymes such as alkaline phosphatase and tryptophane synthetase are among the systems that look especially favourable for such combined genetic and chemical studies.

Evolution

Presumably DNA replication bears no immediate relation to its informational content. Biologically useless DNA is replicated just as faithfully as that playing a vital role. Presumably, too, the mutation process is a random affair. If so, meaningful DNA sequences are much more likely to be made less useful through random mutation than they are to be converted into sequences more useful to the organism of which they are a part. In this sense they may be likened to random typographical errors in a useful message. Direct experiment verifies this expectation; most mutations are unfavourable in the context in which they occur.

If mutations are mostly unfavourable but are as faithfully reproduced as are their normal counterparts, why do they not accumulate with successive rounds of replication just as a typist would accumulate errors in the Lord's Prayer if she were to type copies in succession, each from the previous typing, in a purely mechanical way without proofreading or correcting errors! The answer is that biologically unfavourable mutations specify organisms with reduced reproductive fitness. The errors in their DNA are not corrected but the lines of descent carrying such errors are statistically bred out of existence over a shorter or longer number of generations depending on the degree of reduction in reproductive fitness. We call this natural selection.

Positive evolutionary progress depends on rare favourable mutations that increase reproductive fitness. They gradually replace the ancestral types from which they arose.

Modern concepts of organic evolution hold that all living systems have evolved gradually, mutation by mutation, from pre-existing organisms. Sometimes, as in parasites, it is advantageous to become simpler and to count increasingly on the host for raw materials, a proper environment and protection against enemies. But from the beginning, the overall trend in many lines such as our own has evidently been toward greater complexity.

Speculation as to how organic evolution began in the first place leads to the conclusion that there is no clear qualitative break in the sequence of events that spans the advent of life on earth. This is only another way of saying that we cannot clearly distinguish between living and non-living systems. No matter what system one contemplates, it is possible to imagine a closely related one, only slightly simpler, that could have given rise to the former by a single mutation-like step.

The simplest living systems we know today are viruses. Tobacco mosaic virus particles are submicroscopic rods about 800 Å units in length. They consist of a cylindrical protein coat and an RNA core, the latter being made up of about 6000 nucleotides. In a living tobacco cell infected with a particle of this virus more viruses are synthesised. The bacterial virus ϕX174 contains about the same amount of nucleic acid. Its units are almost spherical. They, too, have a protein coat and a nucleic acid core, but their nucleic acid is DNA, not RNA.

Some people say such viruses are not living—that they cannot carry on metabolism, synthesise their component parts, or do any of several other things that living organisms do. But they do reproduce their kind, given a proper environment. And they are mutable, and hence capable of organic evolution. Whether one calls them living or not depends on one's definition of life and that in the end must be purely arbitrary.

Let us imagine that virus-like systems were

among the earliest 'organisms' to evolve on earth. They were not like present day viruses, for there were no living cells from which they could derive their parts—nucleotides, amino-acids, perhaps a few enzymes, etc. We can reasonably believe that at that stage of the earth's history there were myriads of spontaneously formed organic molecules around, including nucleotides, amino-acids, proteins, etc., and that these were the building blocks of the postulated virus-like creatures. After all we now have abundant experimental evidence that a variety of organic molecules are formed spontaneously under conditions assumed to have been characteristic of parts of the earth's crust a few thousand billion years ago (Miller, 1957).

If the building blocks of the postulated virus-like systems were around, would they not have interacted, again spontaneously, to form nucleic acids, proteins, etc.? Nucleotides interact in the Kornberg system to form DNA capable of replication. Since the role of man in this experiment is merely that of making the conditions more favourable for this particular reaction—that is, increasing its probability—would it not have occurred in his absence when the conditions became right?

As every organic chemist knows, organic molecules are formed through the interaction of inorganic molecules—again when the conditions are right. And as every inorganic chemist knows elements interact to produce inorganic molecules. Nuclear physicists tell us that elements themselves evolve from simpler elements as a result of processes that are both natural and inevitable, given the appropriate circumstances.

Thus it is clear that the sequence: hydrogen—helium — beryllium-8 — carbon — oxygen—other elements—water—other inorganic molecules—simple organic molecules—more complex organic molecules like nucleotides, amino-acids, and small proteins—nucleic acids capable of replication—nucleic acids protected by protein coats—virus-like systems with protein coats serving catalytic functions—multigenic but subcellular organisms—simple cellular systems like bacteria—autonomous cellular forms like algae—protozoa—multicellular plants and animals and, in our line of descent, man himself—is a natural one that could have arisen by steps no one of which need have been larger than the individual mutational steps we know in today's living systems.

In the beginning there was a universe of hydrogen. How and when it was created—or whether it is and always has been in a steady state of continuous creation—science knows very little. In whatever way the universe began, there must have been built into it from the very beginning the potentiality of essentially unlimited orderly evolution.

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ECHOES from the Past

The Progress of Chemistry

Such being the comparatively discouraging circumstances under which chemistry is prosecuted in this country, it is not surprising that neither the number of investigators, nor the amount of new facts added to our knowledge during a given time will bear a favourable comparison with the chemical activity of other and more favoured nations. In the year 1866, 1273 papers were published by 805 chemists being at the average rate of 1·58 paper for each investigator. Of these, Germany contributed 445 authors and 777 papers, or 1·75 paper to each author; France 170 authors and 245 papers, or 1·44 paper to each author; the United Kingdom 97 authors and 127 papers, or 1·31 paper to each author; whist other countries furnished 93 authors and 124 papers, or 1·33 paper to each author. Our case is even worse than it appears to be from these figures; for a considerable proportion of the papers contributed by the United Kingdom were the work of chemists born and educated in Germany, but resident in this country. I am not aware how far a like comparison as regards activity in research obtains in other sciences; but if the United Kingdom takes a similar position in them, it is nothing less than a national disgrace that a country, which perhaps more than any other, owes its greatness to the discoveries of science, should do so little towards the extension of scientific research.

Fortunately, however, this national apathy has not been shared by individual chemists, and the year has not passed without several important additions to our knowledge.

Professor E. Frankland, F.R.S.,
B. A. Meeting, 1868.

Crossing The Channel

There are two main projects, more or less, before the public—one for bridging the Channe , and the other for tunnelling beneath it. Before analysing these projects I would make one general observation, viz. that any project involving an outlay (inclusive of interest during progress) of from forty to fifty millions sterling, and requiring from forty to fifty years for its execution, cannot with reason be entertained.

With regard to the Bridge project, the latest proposition would appear to be to span the channel by a viaduct consisting of openings of three thousand feet each. The platform must of necessity be upwards of two hundred feet above the level of the sea. The piers would be erected on islets founded in a depth of water of thirty fathoms. Now, bearing in mind that to bridge the Thames in the most economical manner involves a cost of about £125 per lineal foot, and applying this as a standard, contrasting the facilities in the one case with the obvious enormous difficulties and contingencies in the other, the relative cost of the latter must greatly exceed four times that of the former; the minimum cost, therefore, of the channel viaduct cannot be taken at less than £500 per lineal foot, which at once brings the cost up to fifty millions sterling, without taking into account current interest. With these remarks we may dismiss the Bridge question.

G. P. Bidder, B. A. Meeting, 1868.

INCREASING THE EFFECTIVENESS OF WESTERN SCIENCE

The following is a summary of recommendations arising out of a report made by a group of most distinguished scientists in N.A.T.O. countries to the Science Committee of the North Atlantic Treaty Organisation. The full text of the report is being distributed in this country by the Central Office of Information at the request of the Foreign Office.

All Western nations, and indeed all nations, should recognise that pure and applied science play a fundamental role in national development. Science represents a social and political force of decisive importance.

The principal recommendations made in this Report may be summarised as follows:

I. National Planning and Support of Science

A. All Western nations should have one or more science councils or organisations responsible for the support of fundamental and applied science, and for the maintenance of quality and breadth of scientific education. The group in charge of such organisations should possess executive authority and should include scientists with demonstrated executive ability.

B. A goal of Western nations should be to devote as much of their national income as possible to encourage research and development appropriate to their needs and their interests. For basic scientific research we recommend a level of the order of 0·2 per cent of the Gross National Product as a target for all countries. For applied research and development the experience of technically advanced countries indicates that a goal of 2 per cent of Gross National Product is both desirable and achievable.

II. Increasing Quality and Numbers of Scientists and Technicians

A. Measures should be introduced by all countries to increase the numbers of their scientists. Apart from general educational programmes, whose object would be to kindle an enthusiasm for science in secondary schools, all governments should consider:

(i) The extension of the period of compulsory education to 16 years of age and, where necessary, the provision of financial assistance for higher education.

(ii) The increased provision of opportunities for higher education in science.

(iii) The improvement of the terms of service of academic and scientific institutions.

(iv) Where lacking, the introduction of national prizes in recognition of outstanding work in science, particularly by younger men.

B. Since a training in science provides a valuable educational discipline and a basis for understanding much of our modern culture and some of the major forces which transform society today, an education in science should not necessarily be limited to those destined to become professional scientists.

C. Attention should be given in many Western countries to the reform of the structure of universities and other institutions concerned with the advancement of science, with particular respect to number of professorial chairs, opportunities for advancement, matters of salaries, staff-student ratio and international exchange. The exchange of scientists between industries and universities should be encouraged; more specifically, there should be no obstacles to the transition of senior scientists from industry to universities.

D. The teaching of science in secondary schools should be improved. All countries should introduce measures to increase the number of highly qualified teachers. Combining part-time teaching in secondary schools with work in universities should also be considered.

E. Measures should be devised to encourage women to enter professional scientific occupations in greater numbers.

F. The training of technicians for science and technology requires greater national attention in order to assure the greater supply of highly skilled

individuals. Attention should be given to the establishment of new Technicians' Training Institutions, co-operative training arrangements permitting combined work and study, and the extension of correspondence training. This matter is particularly important in developing the technical capacity of under-developed nations. Standards of teaching and requirements for examinations should conform as far as possible to norms accepted in highly developed countries.

III. Eliminating Obstacles to Research by National Action

A. The national agencies responsible should do all in their power to remove the obstacles, such as those inhibiting granting of visas, which reduce the free inter-change and employment of scientists among some of the Western nations. The countries should release universities and government research institutes from the traditional administrative regulations which too often impede the activities and growth of these institutions.

B. Nations should encourage expansion of research in industry by granting tax reduction on the funds which industrial organisations contribute to research, either in their own or in other laboratories. Donors of gifts for research to universities and non-profit making research institutes should also be given tax reductions.

C. Nations where currency is controlled should allow scientific research organisations access to the foreign currency necessary for the purchase of equipment and other needed materials.

IV. International Research Co-operation

A. Research and educational centres serving the needs of two or more countries are proposed in several fields of science and engineering which have particular importance at the international level. Those discussed in the report include the following fields: oceanography, meteorology, ecological effects of pesticides, science of materials, and space science. Such centres could be distributed among different nations and preferably be attached to universities. Alternatively, one or more of such centres could form part of an International Institute of Science Technology or an Atlantic or European University. The establishment of an International Institute of Science and Technology merits further study by an appropriately chosen group.

B. International funds should be made available to assist the technically less developed nations, especially in the North Atlantic family, to promote science and engineering at the national level, on condition that such funds are used to mobilise national funds for this purpose.

C. Every encouragement should be given by the international agencies, such as N.A.T.O., U.N.E.S.C.O. and O.E.E.C., which sponsor science in the West, to promote the exchange and employment of scientists between nations. This should be done in close co-operation with the national agencies.

D. I.C.S.U., in collaboration with the International Federation for Documentation and U.N.E.S.C.O., should be asked to do everything possible to improve documentation by the following actions:

(i) Organisation of collaboration between editors of chief scientific journals to ensure uniformity in publication practices.

(ii) Affiliation of principal documentation centres within countries.

(iii) The evolution of a single international system of indexing.

(iv) Arrangements for the provision in all cases of authors' abstracts.

(v) Encouragement of additional reviews of broad scientific fields.

(vi) Reduction of airmail tariffs for transmittal of single copies of scientific publications to libraries and scientific associations.

The proliferation of scientific journals should be discouraged.

The agencies concerned with documentation of scientific literature should receive greater support from agencies sponsoring science in the West.

E. An international centre in auxiliary support of science is proposed, namely a clearing house to expedite the transfer of research equipment.

F. International agencies which distribute cultural literature should include scientific publications which provide an accurate picture of current scientific developments.

G. All international organisations, including N.A.T.O., should co-ordinate their scientific and educational activities as closely as possible.

ATMOSPHERIC POLLEN AND SPORES AS CAUSES OF ALLERGIC DISEASE: Hay-fever, Asthma and the Aerospora

By H. A. HYDE and D. A. WILLIAMS

I. The Medical Problem

Hay-fever is a common illness due to pollen; in Great Britain it is most often due to grass pollen, and affects some 0·5 per cent of the population; and between 30 and 40 per cent of hay-fever sufferers also have summer asthma due to the same cause.

The prevalence of asthma is just twice that of hay-fever; it affects around 1·0 per cent of the population. Asthma is not only a prevalent illness but also one which causes much incapacity, some 35 per cent of asthmatics being occasionally, and a further 15 per cent frequently, incapacitated. Deaths from asthma are comparatively rare but they do occur. The death rate from asthma in England and Wales in 1955 and 1956 was 5·4 per 100,000 of the population (Williams, 1958).

The causes of asthma are at present only partially understood. Infections of the upper air passages, psychological factors, and also extrinsic allergens all play an important part in precipitating attacks (Williams *et al.* 1958). By extrinsic allergens are meant inhalants or dusts, such as animal dander, house dust, pollen and fungal spores, and also, but less frequently, foods. The tendency to develop 'allergies' is largely due to heredity, but a further predisposing cause is the extent of the exposure, the greater the exposure the greater the tendency, with some substances having a greater tendency to cause symptoms than others.

The part played by allergens in any particular case may be traced in part by testing the patient's skin with extracts of suspected allergens and by inhalation or provocation tests, that is by observing and measuring the effect on the patient's breathing of inhaling extracts of suspected allergens. Skin testing, which is widely practised, does not, unfortunately, give complete proof that the allergen is causing the patient's symptoms. Inhalation tests are only possible at present in very special clinics. In the last resort it is only by taking a careful history of the illness and correlating it with the patient's exposure to the allergen possibly concerned, that correct diagnosis is possible. Therefore, in regard to pollens and fungal spores as allergens, it is to the botanist that the doctor must turn for information to confirm that these airborne spores in fact are the cause of attacks. He wants to know when the suspected spore occurs in the air and, if it is prevalent during one part of the year only, how long its season lasts and how its greatest abundance varies from time to time. Given this information he can confirm or otherwise that his patient's symptoms fit in with the time and degree of exposure.

Thommen (1931) enunciated five postulates that must apply to a plant before it should be suspected of causing epidemic or widespread hay-fever. They are:

1. The pollen must contain an excitant of hay-fever.
2. The pollen must be anemophilous.
3. It must be produced in sufficiently large quantities.
4. It must be sufficiently buoyant to be carried considerable distances.
5. The plant producing the pollen must be widely and abundantly distributed.

Mutatis mutandis these postulates apply equally well to airborne fungal spores.

Although hay-fever was shown in 1873, by the brilliant research work of Charles Blackley of Manchester, to be undoubtedly due to pollen, the word 'allergy', which means a different or altered reaction, was not coined until 1906; and it was not until fifty years ago, in 1909–10, that attention was first drawn to the possibility of a new approach to

asthma, and that it was realized that what had been previously termed idiosyncrasies, and regarded as interesting but unusual reactions, might in fact play an important part in this disease; in a word that asthma might be, what many now term it, an allergic disease.

It is only during the last twenty-five years or so that the methods of investigation of these idiosyncrasies or allergies as a cause of asthma have become reasonably precise. During this time the role of extrinsic allergens has slowly but steadily gained recognition and the number known to be involved has simultaneously increased. If the past is anything to go by, then we can reasonably expect new allergens to be discovered. It is only during the last ten years, thanks to advances in our knowledge of the fungal spores present in the air of this country, that doctors have been able to find and treat specifically many cases of asthma, mainly summer asthma, whose cause was not previously known. But there are still many patients with summer asthma and exacerbations of asthma in the summer, the cause of which is not known. In the search for new allergenic substances in the air, which might account for these cases, the role of the botanist is again of primary importance, for only after a particular kind of spore has been found to occur abundantly and regularly in the air, i.e. to fulfil the botanical requirements of Thommen's postulates, can the doctor begin his investigation knowing that there is any likelihood that this spore may be a cause of widespread illness.

At present, it is generally accepted that allergens play a dominant part in the causation of asthma in some 30 per cent of asthmatics; those most commonly so affected are children and adults up to around the age of forty-five years. In particular fungal spores as a dominant cause of asthma at present are known to affect some 5 per cent of asthmatics and to play a subsidiary part in others.

Of all the inhalant allergens or dusts capable of causing asthma, none lend themselves so readily to scientific investigation as do pollen and fungal spores, and it is a reasonable presumption that fungal spores yet to be determined do play a part in the causation of attacks at least in a proportion of those whose asthma is worse in the summer or autumn. For this work the closest collaboration between botanists and doctors is essential.

D.A.W.

II. The Botanist's Response

Hay-fever is due entirely, and asthma in part, to the regular and normal presence in the air of an invisible and variable but ubiquitous population of plant spores (collectively called—to use Gregory's useful term—the aerospora). These diseases pose a whole range of problems which can only be solved with botanical help.

The scientific study of inhalant allergy was begun (as stated above) by C. H. Blackley of Manchester, who day by day in 1866 and subsequent years trapped pollen from the air on a sticky slide and, by correlating the results with his own and others' symptoms, proved for the first time by the experimental method that beyond doubt hay-fever could be produced by pollen. His lead was not followed until many years later, when in 1916 systematic pollen trapping, this time coupled with a generic analysis of the catches, was revived in the U.S.A. By 1940, largely as the result of the efforts and influence of O. C. Durham (1946), almost the whole of America north of Mexico had been surveyed in this way. One such investigation was carried out in Denmark during the early 1930's. Between 1935 and the present time similar surveys, some more, some less complete have been made in eleven countries in Europe, and others, each extending over one to three years have been made in Australia (three States), New Zealand, South Africa, Brazil and the Argentine.

Fungus spores were not recognised as allergens until much later than pollen grains. Blackley in the course of his experiments inhaled a whiff of *Penicillium* spores, incurring thereby a severe attack of hoarseness and catarrh, and so very nearly stumbled on fungus allergy, but he did not pursue the subject. The first definite proof that the inhalation of fungus spores produced asthma came from the U.S.A. and related to *Alternaria* growing on vegetable refuse indoors. But other workers, notably Feinberg (1946) of Chicago, conjectured that if fungus spore allergy were general it must be related to spores present (like pollen) in the general atmosphere, and systematic surveys of atmospheric fungus spores were therefore initiated at several centres in the U.S.A. during the 1930's. After World War II similar investigations were begun in other parts of the world, notably in several countries in Europe and also in New Zealand and South Africa. The first such observations in Great Britain date from 1942.

The methods which have been used for the appraisal of airborne populations of spores are too numerous for detailed mention. The great majority of workers have trapped them on an adhesive surface and then scanned the surface. Blackley and most of his successors have used a microslide exposed horizontally. It was for many years assumed that particles suspended in the air were merely sedimented on to such a slide under the influence of gravity, hence the name 'gravity slide'. It is now known that sedimentation under gravity plays only a minor part, but nevertheless the misnomer 'gravity slide' remains.

But it was obvious that the study of inhalant allergy demanded an apparatus by means of which the spore content of the atmosphere per unit volume could be obtained by direct counting. Up to now the most successful such apparatus and the most widely used has been the Automatic Volumetric Spore Trap devised by Dr. J. M. Hirst (1952). The essential feature of this apparatus is the impaction unit, an airtight vertical cylinder provided with a lateral orifice through which air is sucked by a vacuum pump. Spores contained in the indrawn air are impacted on to a sticky microslide which is drawn by clockwork past the orifice at 2 mm. per hour. The slide is later scanned under the microscope for pollen grains and other spores; from the counts so obtained both the mean 24 hour concentrations in grains per cubic metre and hour to hour values may be computed. Many kinds of fungus spore cannot be determined closely by visual examination alone, so that the fungi concerned elude detection by the Hirst Trap. Some of these—belonging to the culturable moulds—can however be assessed by trapping them on the surface of nutrient media and identifying the resulting colonies (see below).

It is convenient in the first instance to consider pollen grains and fungus spores separately. A review of the relevant literature (Duchaine, 1959; Wodehouse, 1945) shows that, out of the 333 families of flowering plants (spermatophytes) now extant, 38 contain at least one species stated to be allergenic, but only 19 include even a single species which in any part of the world is regarded as of primary importance (for a species or a genus may be important in some one part of the world only, but not necessarily over the whole of its range). This 'hard core' of the world's hay-fever flora comprises representatives of 44 genera, 22 of which belong to one or other of two families only, viz. *Compositae* (6) and *Gramineae* (16): hay-fever toxicity, as R. P. Wodehouse has said, appears to be a family character.

It is customary to consider hay-fever plants under the three headings trees, grasses and other herbs ('weeds' so called in this connection.) Eleven genera of broadleaved trees—all of them widespread anemophilous types—are regarded as of primary importance in North America, but only one conifer (a *Juniperus*). Only four tree genera are so rated in any part of Europe, viz. the oaks, paper mulberry and hop hornbeam in Continental Europe, and (surprisingly perhaps) elder (*Sambucus*) in the Mediterranean Basin; and in the tropics only the coconut palm (in the West Indies). Since pine trees shed such vast quantities of pollen, the absence of the genus *Pinus* from this list is remarkable; but most physicians agree that, as an allergen, pine pollen is negligible. Sixteen genera of grasses come into the top class as hay-fever plants; these include in Europe, North America and New Zealand, all the principal meadow grasses, but only one cereal (Sorghum in the U.S.A.). Two genera are prominent in the tropics, viz. *Eragrostis* and *Hyparrhenia*. Bermuda grass (*Cynodon dactylon*), important in this respect in the Mediterranean, the West Indies, Central and South America and the U.S.A., seems to be one of the most widespread hay-fever plants in the world. The pollen grains of grasses in general are all very similar. The cereal type of pollen grain can be distinguished from the smaller and usually much more abundant wild grass type, but genera cannot in general be distinguished. The importance of the various grasses therefore has to be assessed by their abundance and apparent pollen productivity, and by the result of skin tests. All the grasses so far investigated by means of experiments with animals have some antigens in common. The only herbaceous plants other than grasses prominent in Europe are ribwort plantain (*Plantago lanceolata*) in Temperate (Continental) Europe, and pellitory-of-the-wall (*Parietaria* spp.) in the Mediterranean. The most prevalent of such plants in North America are the amaranths, chenopods, hemp, plantain, mugworts, and above all the ragweeds (*Ambrosia* spp. and related genera).

When the investigation of plant spores in the air over Great Britain was first contemplated in 1941 no exact information existed on the kinds of pollen (or other spores) occurring in the air, or even of their dates of liberation, still less their relative abundance. Systematic trapping began at Cardiff (where it has continued without a break since January 1942) and has since been extended in most instances for a period of a year or more to fifteen other stations from the Scillies to Aberdeen and situated in urban, rural, coastal, mountain and maritime situations (Hyde and Williams, 1944-6; Hyde, 1950–2 and 1952–9). The gravity slide method has been used at all stations, but in addition since 1954 a Hirst Trap has been operated continuously at Cardiff (Hyde, 1959). An independent Hirst Trap survey of pollen and spores in the London area, begun by Miss (now Dr.) Elizabeth Hamilton, also in 1954, is still in operation (Hamilton, 1959).

The order in which the more abundant types of pollen are found in the air and their duration from year to year are shown in the calendar (Fig. 1). This order is almost constant, though in some years the 'procession' begins early and is long drawn out, and in others it begins late and is consequently telescoped into a shorter period. Of the thirty one types shown in the calendar, the most abundant on the average are grass, four kinds of tree (oak, birch, ash and elm) and three kinds of herbaceous 'weed' (plantain, nettle and the sorrel-dock type). If numbers of grains are to be taken as the criterion, the plants from which these eight types of pollen are derived are the chief hay-fever plants in Great Britain: they are all more or less abundant and ubiquitous. Plane, which is extremely abundant only over London, also deserves special mention.

Grass pollen is consistently the most abundant type all over Britain, the least variable in its period of prevalence and by far the most important in its effects. Every year the count rises rapidly from a few grains per cubic metre in late May to several hundreds in mid-June. The maximum phase always comes between June 10 and 24 and the season is virtually over by August 1. The mean daily concentration oscillates violently from day to day, according to the occurrence or non-occurrence of bright sunshine. The hourly count varies much more widely: on sunny days during the peak period the count rises daily, late in the afternoon, to between 1000 and 1750 grains to the cubic metre. (A figure of 4000 has been registered by Dr. J. M. Hirst at Rothamsted.) But on a sunless day the figure may remain near zero. Long sunny periods during June occasion much discomfort or even suffering to hay-fever patients.

But, while during bright sunny weather the pollen count may rise daily to values ranging in some places from 1000 to 4000 grains to the cubic metre outdoors, the quantities registered simultaneously inside a house with the windows and doors closed are by comparison almost negligible. Hence an adult man engaged in violent exercise outdoors may easily inhale 500 times as much grass pollen as he would quietly reading in a closed-up room indoors. Pollen concentrations like those described probably occur over the whole of the lowlands of England and Wales. Certainly they occur for example in central London, and in or near a grass field they go much higher. But they fall off greatly in the mountains and also as one goes right out to sea: though counts made on the Isles of Scilly for example show that they are too near Cornwall to form a refuge from hay fever.

It is fairly easy, given our present knowledge of the variation in grass pollen concentration with time, place and weather to draw up a 'hay-fever code' for the guidance of patients who are sensitive to grass pollen: a copy of this code is in fact handed out yearly to every patient at the Cardiff Asthma Clinic.

The periods of prevalence of the various kinds of tree pollen are in general short and, if intense, only so in certain years: any particular type may in some years almost drop out of the calendar. One is less likely to become sensitised to any kind of pollen (like ash or oak or birch), to which one might be exposed in quantity only briefly and occasionally, than to grass pollen, to which one is exposed in great quantity for several weeks every year. It is not surprising therefore that tree pollens are regarded as relatively unimportant in Britain. It should also be added that their variable phenology and abundance greatly complicate both diagnosis and the results of treatment: which may also in part account for the fewness of the cases reported. The pollens of the principal non-gramineous herbs concerned ('weeds') have long but not in general intense seasons. The one and only kind which

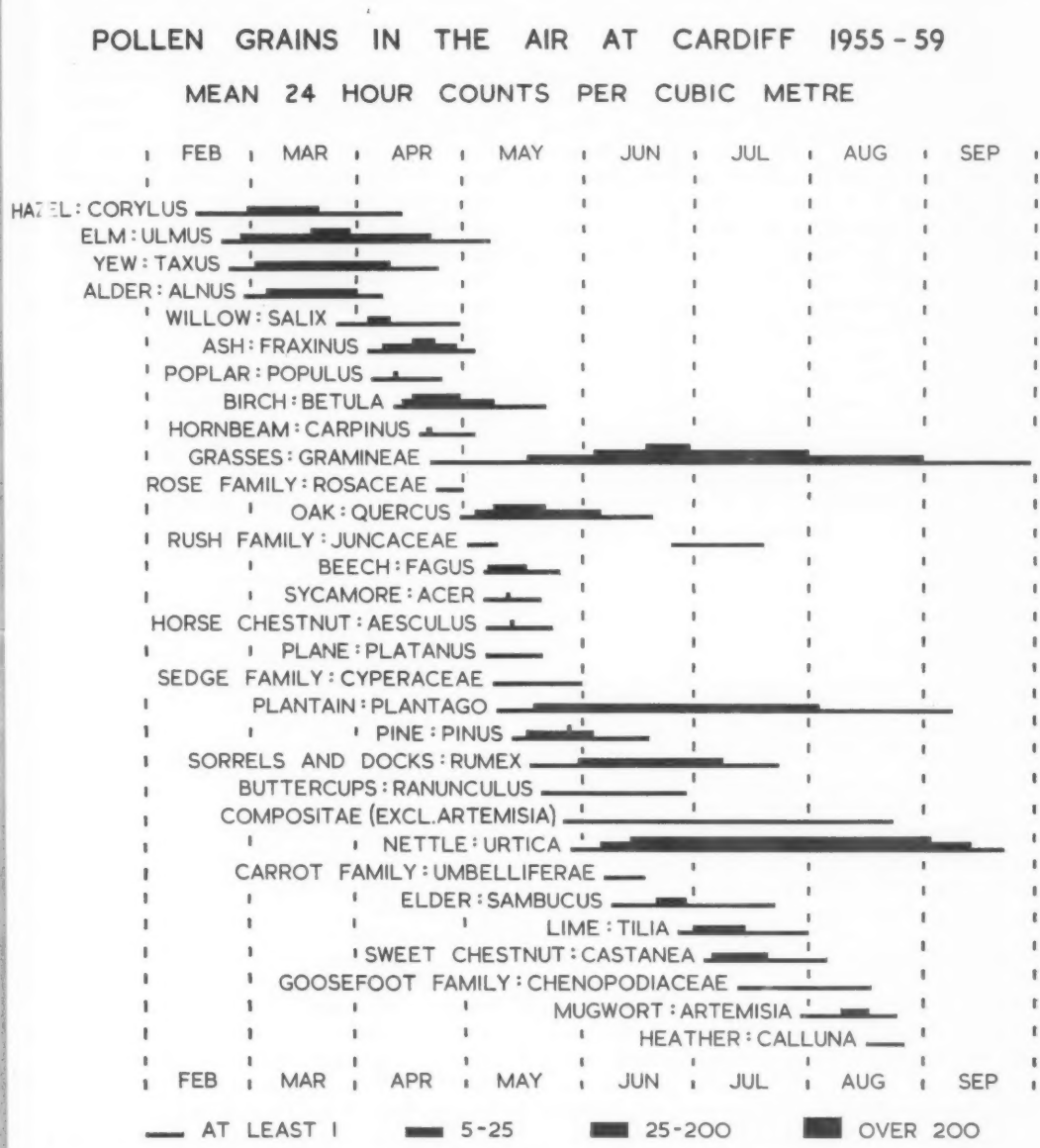

Fig. 1.—Pollen calendar for Cardiff based on counts obtained with a Hirst AVST situated on the roof of the National Museum of Wales, Cardiff, 60 ft. above ground level and 45 ft. O.D. The concentrations indicated were attained on average during the periods shown except that certain trees (poplar, willow, hornbeam, beech, *Acer* and horse-chestnut) reached a mean 24-hour count of over 5 grains per cubic metre in certain years only. For further explanation see text.

produces numerical concentrations even remotely approaching those of grass pollen is nettle, the mean daily count for which at Cardiff may rise to 200 to the cubic metre as compared with 600 for grasses (Hyde, 1959). Nettle is related to pellitory-of-the-wall (*Parietaria*), which, as already noted, is regarded in Mediterranean countries as, if anything, a more important allergen than grass pollen, and in consequence clinicians are looking for nettle pollen allergy in Britain; but since nettle pollen grain for grain is only one-twelfth as bulky as grass pollen its abundance is more apparent than real (see below).

The fungus aerospora has not been surveyed so long or so completely as its pollen counterpart. American allergists during the 1930's had observed on their slides large quantities of the large conidia of *Alternaria* (a common and widespread saprophyte especially abundant on cereal crops) and regarded it as a common cause of asthma, especially in the Middle West; and a two-year census of *Alternaria* at Cardiff in 1942–3 showed that its spores were present in numbers regularly in late summer. But until recent years the study of the fungus aerospora has been carried on chiefly by the use of culture plates. As usually practised this method entails exposing to the air for a short period a petri plate containing a suitable nutrient medium such as Sabouraud's agar. After five day's incubation at room temperature the resulting mould colonies are counted and as far as possible determined at least as to genus. Hyde and Williams showed, by means of a twelve months' run by this method at Cardiff that, while the moulds *Penicillium*, *Pullularia*, *Phoma*, *Botrytis*, *Aspergillus* and *Alternaria* occurred regularly in significant numbers, the most abundant mould spore in the air by far, especially in summer, was *Cladosporium*: indeed their counts indicated that during the summer this mould was present in greater numbers than had previously been recorded anywhere, and also indicated, somewhat surprisingly as it then seemed, that it was much more prevalent in dry and warm rather than in damp weather. Very high concentrations of *Cladosporium* spores during summer were observed about the same time or later by several other workers in various parts of Britain.

The Cardiff survey of culturable moulds was continued during 1951 to 1953 by M. Richards and extended, in collaboration with other workers, to seven other stations in England, Wales and Scotland. It was found that the great bulk of the catch (96 per cent) at Cardiff was composed of eleven genera only. Six of these, *Cladosporium*, *Pullularia*, *Epicoccum*, *Botrytis*, *Alternaria* and *Candida* occurred chiefly in summer, two (*Aspergillus* and *Oospora*) in winter, while the remainder (*Penicillium*, *Phoma* and *Sporotrichum*) were almost equally frequent at all seasons. This pattern of abundance was repeated at all stations, but two important quantitative differences distinguished the rural catches from those made in the large towns: *Cladosporium* formed 70 to 80 per cent of the total catch in rural areas as against only 40 per cent in the large towns, while *Penicillium* on the other hand was commoner in the large towns than elsewhere (though it nowhere approached *Cladosporium* in average frequency) (Hyde, Richards and Williams, 1956).

As we have already seen the introduction of the Hirst Trap marked a very great advance in the technique of the assessment of atmospheric spore populations: this apparatus has been used to sample fungus spores at several places in Great Britain, first at Rothamsted and then elsewhere, and by its help we have been able to form a complete picture of the fungus aerospora, as distinct from the partial impression derived from culture plates. With it Gregory and Hirst (1957) confirmed the high abundance of *Cladosporium*, and in addition first demonstrated the comparable frequency of the spores of the sac fungi (Ascomycetes) and the gilled and spore fungi (the higher Basidiomycetes), and also the existence of a numerically large population of shadow yeasts (Sporobolomycetaceae). Hirst also showed, and Dr. Elizabeth Hamilton has since confirmed, that during dry weather many types of fungus spore show a marked diurnal periodicity, giving maximum counts during the afternoon, while others, which in dry periods occur in quantity only in the early morning, completely replace the dry-air spora during rain (Hirst, 1953; Hamilton, 1959). The periods of occurrence and of greatest abundance of the principal types of fungus spore trapped and counted at Cardiff during the year can be seen from the calendar in Fig. 2.

If the various kinds of plant spore are arranged in order of their numerical abundance at Cardiff it is found that *Cladosporium*, with an average mean

FUNGUS SPORES IN THE AIR AT CARDIFF 1957–58
MEAN 24 HOUR COUNTS PER CUBIC METRE

Fig. 2.—Fungus spore calendar for Cardiff: counts obtained from same apparatus as in Fig. 1. The concentrations stated were reached during the periods shown, in one year or the other but not necessarily in both: thus in 1958 *Cladosporium* did not at any time exceed 10,000.

daily concentration (1958-9) of about 1200 spores per cubic metre, heads the list, followed by eight other types of fungus spore with counts ranging from about 600 down to 20/m³, and only then by grass pollen with 19·6, and other pollens all of them with 10 or fewer and many with fractional values. (It should perhaps be emphasised that these concentrations have been averaged over the whole year; the mean daily concentrations to which patients are actually exposed during the 'seasons' of the various types of spore may rise to 30 times the average and at peak hours the values may be several times as great again.) However, most kinds of pollen grain are much larger than most kinds of fungus spore: numerical indices of the abundance of the various kinds of spore are likely therefore to be misleading as guides to their relative importance. But their volumes can easily be computed, and when these are used to weight the numerical frequencies it is possible to state the average abundance of the principal kinds of pollen grain and spore on a common basis of cubic microns per cubic metre, as in Table 1.

TABLE 1

POLLEN GRAINS AND FUNGUS SPORES IN THE AIR AT CARDIFF, 1958–9

Average mean daily volumes in cubic microns per cubic metre

1	Grasses	288,400
2	*Cladosporium*	190,500
3	Ascospores	99,200
4	Basidiospores	96,000
5	*Ulmus* (elm)	51,700
6	*Epicoccum*	48,100
7	*Alternaria*	16,800
8	*Quercus* (oak)	13,400
9	*Botrytis*	12,300
10	*Betula* (birch)	11,600
11	*Urtica* (nettle)	11,400
12	*Ustilago* (smut)	8400
13	*Erysiphe*	8300
14	*Alnus* (alder)	8000
15	*Plantago* (plantain)	7800
16	*Fagus* (beech)	7400
17	*Tilia* (lime)	6500
18	*Rumex* (Sorrel and dock)	6000
19	*Corylus* (hazel)	5200
20	*Fraxinus* (ash)	4600
21	*Tilletiopsis*	4300
22	*Sporobolomyces*	3300

Note: Nos. 5 (*Ulmus*) and 17 (*Tilia*) stand higher at Cardiff than they would but for the unusually large number of elm and lime trees in the city centre.

The figures in this table relate to one station and to a period of two years only. They take no account of the dry weights of the spores concerned (on which the data are very scanty); and so at present they are only tentative, but the order in which the various types now fall does at least appear to have some significance: it confirms present views on the importance of some kinds of spore as allergens, and it may point the way to further advances in knowledge.

Grass pollen now heads the list: it is of course our principal allergen, and the other kinds of pollen listed here (Nos. 5, 8, 10, 11, 14–20) have all been regarded as allergenic even if they are not of primary importance in Britain. *Cladosporium* comes second; as the one type of fungus spore known to be a widespread cause of asthma, it merits and is receiving special attention. De Vries (1952) showed that spores of at least six species of this genus are to be found in the general atmosphere, as against the two formerly known to be present. Mr. R. Harvey is engaged in assessing the relative importance of these six species in the air of Cardiff and in elucidating their respective responses to factors in the environment (Harvey, 1960). Three other culturable moulds come respectively sixth, seventh and ninth: *Epicoccum* (No. 6) has been placed high in the list of suspects in Italy, and *Alternaria* (No. 7) and *Botrytis* (No. 9) are among the proven causes of asthma in Britain. *Ustilago* (smut of cereals, especially oats) (No. 12) is regarded in the U.S.A. as an important allergen. *Sporobolomyces* (No. 22) ranks much higher near ground level in a damp locality, as was shown by Gregory and Sreeramulu (1958). Ascospores (No. 3) are determined for the most part under form or colour headings, not as taxa. Similarly with basidiomycetes (No. 4): a few of these are assigned to their genera, but most of them are put down as either coloured or hyaline. Gregory and Hirst suggested that, in view of their large numbers, basidiospores merited serious consideration as allergens; and indeed those of one kind, viz. *Merulius lacrymans* (dry rot) at least satisfy Thommen's postulates (A. W. Frankland). It may well be that the next advance will come in this direction: it looks as if the investigation of fungus spores as allergens has only just begun.

To resume then: the pursuit of inhalant allergens is not entirely haphazard. Some types are inherently more likely to evoke symptoms than others: among flowering plants high allergenicity is confined to a relatively small number of families; we cannot yet say how it is distributed among the fungi. Other things being equal the most abundant types of spore are the likeliest allergens. Some kinds of spore are present in the air in effective concentration year after year; these are much more likely to produce sensitisation than those whose concentrations become high at longer and less regular intervals. When the atmospheric concentrations of different kinds of spore are being compared numbers should be weighted for size.

Continued and increasingly detailed observation of the aerospora will be essential if the physician is to be provided with an adequate record of the endlessly shifting background to his studies of allergic disease. From this point of view the aerospora is a factor, or rather a complex of factors, in the human environment, and its study a contribution to human health and welfare.—H.A.H.

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DRILLING OF DEEP BORE-HOLES

By T. F. GASKELL *British Petroleum Exploration Co. Ltd.*

'Deep' in the context of this paper is about 10 miles. This figure is determined by the project 'Mohole' which is a proposal—put forward by oceanographers and geophysicists—to drill through the earth's crust in order to obtain samples of the rock that comprises the mantle. This paper will deal mainly with techniques of drilling, so that when in future you read about attempts to penetrate the earth's crust you will have some idea of the difficulties involved. But first I would like to recapitulate for you a few pertinent facts about the structure of the earth.

Structure of the Earth

Studies of the travel times of earthquake waves, together with observations made on quarry blasts and other explosions on land and sea, have demonstrated that the inside of the earth can be divided into a *core*, a *mantle* and a *crust*. The core has a density which corresponds to a composition of iron in a fluid state and it extends to about halfway from the centre of the earth. Wrapped round the core is a much lighter solid rock mantle which reaches almost to the surface of the 4000 miles radius of the earth. The crustal rocks, which are the ones familiar to us at the surface, form a skin, which is about 20 miles thick beneath the continents, but which thins to a few miles under the 3-mile depths of the oceans. Since the mantle contains the greater part of the volume of the earth, its chemical composition and its radioactive properties are significant facts in any theories of the earth's formation and subsequent history. Now that oceanographers have demonstrated that the mantle is within striking distance it is natural that attempts should be made to collect samples. This will entail either drilling in the open ocean, where 3 miles of water plus 4 miles of crustal rock cover the mantle, or from an oceanic island or atoll, where the thickness of rock cover is about 10 miles because the mantle here is depressed to form the root of the island.

Although no one has drilled in water 3 miles deep, considerable experience has been gained by oil companies in boring at sea, and on land depths of 5 miles have been reached with conventional equipment. Therefore drilling through the earth's crust does not call for more than doubling our present capabilities, so that although the achievement of this aim may require new techniques, it is quite clearly within reach—practically if not financially.

In the oil industry, bore-holes are normally confined to sedimentary rocks, and although hard rock layers are sometimes encountered, the methods of drilling large thicknesses of the hard basalt which forms the lower part of the crustal rocks have not received much attention. On the other hand, mining engineers have successfully drilled exploration holes more than 6000 ft. deep, in igneous rocks, for example in locating gold accumulations, so that knowledge is available on this aspect of the problem.

Rotary Drills

Most deep borings are made today by the rotary drill, the action of which is well known, and this rotary method of boring into the earth has maintained its place of leadership as the most versatile and economical tool in spite of a great deal of effort that has been spent in devising new systems. This is quite surprising when one visualises the true scale of, say, the deepest hole drilled to date. This hole, like most oil wells had a diameter of

about 6 to 12 inches., and the drill-pipe used was only 3 or 4 in. in diameter, so that the ratio of the length of the drill-pipe to its diameter is about 100,000 to one. A model of this small enough to hang from the ceiling of a room would be a fine wire about $\frac{1}{1000}$th of an inch thick—so the engineering achievement in cutting rock at the end of this tenuous thread is quite remarkable. I often wonder whether the rotary method would have been attempted for these deep holes if drillers had not gradually progressed from shallow borings to the record depths they reach today. Of course, the drill bit is not pushed into the ground in the way that a drill is forced into a piece of wood—the long length of drill-pipe is far too flexible for this. All except the bottom few hundred feet of pipe is in tension, and the weight that forces the bit into the rock is supplied by the extra heavy and stiff sections of pipe. But the bit has to be rotated from the surface, and as you can imagine, 5 miles of 3-in. pipe is not a very easy connecting link for a rotary drive. There is a danger that any hold-up to the bit will cause the pipe to twist off, and in addition there is a large wastage of power due to friction at the walls of the bore-hole. Both of those factors limit the speed of rotating the bit, and hence the rate of penetrating the rock.

It is not surprising that much effort has been put into making a drive which can operate at the bottom of the hole, at the place where the rotary power is required. Electric motors have been used, but the difficulties of handling long power cables under rough conditions have not yet been fully overcome. Success has, however, been achieved with the turbo-drill, which consists of a multi-stage turbine motor driven by water or mud circulated down the drill-pipe. Although the economics of the turbo-drill cannot compete with rotary for normal oil-well drilling, extensive trials in the United States have shown recently that it is better in hard rock formations where the greater power developed at the drill bit and the higher rotation speed show to full advantage. In soft formations the conventional rotary drill is capable of making such rapid footage that any increase of penetration rate gives a very small overall increase in rate of drilling, and this is offset by a shorter life of the drilling bit when using the turbo-drill.

Fig. 1.—D'Arcy's first well, Chiah Surkh—1902–1905.

Percussion Drills

Early oil-well drilling was carried out by percussion rather than by rotary cutters. The rock was chipped away by continued blows with a heavy

chisel which was suspended on a wire-rope. This method is still used occasionally, but cannot often compete with the rotary method. However, some recent developments suggest that a combination of rotation of the bit with an up and down movement may double the rate of rock penetration. Various ingenious mechanisms have been devised to vibrate the bit as it rotates, at frequencies ranging from 1 to 300 cycles per second. Some of these are operated by air pressure and some by the mud that is normally circulated during rotary drilling.

The circulating mud in oil-well drilling performs many functions. In the first place, it is the means whereby the fragments of rock that are cut by the bit are carried to the surface—and incidentally removed from the scene of operation at the bottom of the hole. Almost as much work must be done to grind up a chip as is required to break the chip from the parent rock in the first place. So for efficient drilling any chip must be swept away before the next cutting tooth reaches it. Jets of fluid are directed at the teeth of the drill bit, and in soft formations these jets improve the rate of penetration by a scouring action. The fluid also helps to keep the bit from overheating. This may be of increasing importance in our very deep holes because temperatures of more than 500° F. are likely to be encountered in the rock itself. However, holes have already been drilled in places where abnormal temperatures of this order have been present.

The column of drilling mud exerts a hydrostatic pressure on the bore-hole, and this serves a useful purpose in holding back the walls of the hole from caving, in much the same way as pit-props support the roofs of coal-mines. Not only does mud help to keep the sides of the bore-hole in order, but it also holds back high-pressure fluids—which may be water, oil or gas—from entering the bore and causing trouble at the surface. It is unlikely that high-pressure gas will be encountered in drilling the 10-mile deep Mohole. Borings on coral atolls have already demonstrated that hard basaltic rock is reached at a depth of a few thousand feet, and the seismic measurements suggest that this hard rock continues uniformly to the mantle. Calculations indicate that basalt rock is strong enough to support itself without the help of the mud column, and it appears unlikely that any intrusions of water or gas will be present in such a solid rock. However, this is not certain; but we hope that no difficulties will be forthcoming with high pressures, because special high-density muds add extra complication to drilling, and for cooling and lubricating the bit and for removing chippings, plain water would be easier. If the basalt rock is as strong as we think, it means, of course, that we could dispense with a circulating fluid altogether if any new rock-cutting method was found to have great advantages over the conventional rotating drill bit system.

Fig. 2.—Bit hanging in derrick at Arreton, Isle of Wight, where B.P. Exploration Company drilled an exploratory well.

New Techniques

Among the more fanciful ways that have been tried out for rock drilling is the pellet impact device, in which a stream of high-speed steel balls is fired at the bottom of the boreholes. When the steel balls become worn, they can be augmented by

Fig. 3.—Drillers hoisting the drilling pipe of the drilling rig at Arreton, Isle of Wight, during B.P. Exploration Company exploratory drilling operations.

a further supply sent down in the mud stream from the surface, so that the time-consuming removal of the drill and pipe to renew the cutting bit is avoided. It has been found, however, that the acceleration of the steel balls is a very inefficient process, and furthermore, the method requires that all the rock shall be pulverised, and this inherently calls for more work at the rock face than does the removal of rock fragments.

Another invention designed to produce what is virtually an everlasting drill bit is the Russian spark drill. A condenser discharge across electrodes causes a shock wave in the drilling fluid sufficient to penetrate rock slabs, at least in the laboratory. A more practical form of shock wave drill utilises a series of explosive charges detonated at appropriate intervals of time at the bottom of the hole. A few ounces of high explosive will break up about 6 in. of hard rock which can then be scoured out with a conventional bit. Although steps of 6 in. may appear to be unreasonably short, there are cases where only a few feet per shift are made in oil-well drilling, so that for tough rock the 5 to 10 ft. an hour, claimed as possible with explosive, is good progress.

Most rock can be broken up by intense heat, and holes up to 50 ft. are cut by flame torches in rock and concrete, for making shot-holes in mining and for civil engineering works. It is possible that this method might be adapted to cutting deep holes in basalt, but its success does depend upon spalling of the rock which might be reduced at bottom-hole temperatures and pressures, and the supply of fuel and oxygen would entail some practical difficulties with supply lines running miles into the ground. Other methods of supplying intense heat that have been reported are to use an electric arc; or to direct a highly accelerated 'plasma' stream of argon at the rock.

The most promising way of cutting hard rock is to follow the lead of the mining engineer and the geological laboratories by using diamonds. Diamond core-bits are gaining increasing popularity with the oil industry, since they enable much more complete recovery of core samples to be obtained, and they do not wear out so rapidly as hard steel rotary drilling bits. They are, of course, extremely expensive, and they do require careful handling, since although diamond is harder than rock and so can abrade the rock surface, the individual diamonds can be cracked by impact if the bit is dropped roughly on to the rock. Two main lines of improvement of diamond rock bits are being followed at the present time. The metal matrix which holds the individual diamonds is being made tougher so that it will not allow the diamonds to fall out; for it is the mounting of the diamonds rather than the diamonds themselves which gives way first. One suggested alternative to the conventional diamond crown is to construct a tool of fine chips of diamond mixed throughout the metal, so that as the bit wears an abrasive cutting edge is continually exposed. One proposed design for a diamond bit utilises a high-speed grinding wheel action, in which the wheel is spun rapidly by means of a small turbine, and the whole is slowly rotated by means of the drill pipe. The other development in diamond bits is concerned with designing the channels

through which the circulating mud flows so that no part of the matrix becomes overheated, or is subject to wear by the rock fragments. It appears probable that the diamond bit manufacturers may soon be able to achieve a bit life ten times that which is possible at present.

Drilling Life

It is especially important to have long life of bit when drilling deep holes, because of the time needed to pull out the drill-pipe in order to replace the bit when it becomes worn. For our 10-mile hole it might well take 30 hours for the complete round trip, and as you can imagine, much effort has been applied to circumvent this problem. The reason that drilling derricks are very tall is so that lengths of drill-pipe of about 100 ft. can be pulled before stopping to unscrew the joints. One British inventor has replaced the conventional block and tackle with a hydraulic lift which performs a sort of hand-over-hand motion, thereby enabling the pipe joints to be unscrewed without stopping the steady pull of pipe from the hole. It should be possible to reduce the bit changing time to one-third of the present value with this fully automatic rig. There is another advantage in using hydraulic lift in that the control of movement of the bit will be much less jerky than with a block and tackle hoist. This will allow high-speed drills such as the turbo-drill to be run at optimum pressure on the bottom of the hole, and will thus eliminate sudden surges of speed which wear out the bit. Also there will be less chance of the bit being damaged by sudden impact with the bottom of the bore-hole.

The drill-pipe is normally removed from the bore-hole for another reason. When core samples of the rock are collected they are fed into a collecting tube which fits inside the drill-pipe. This core-barrel as it is called must be brought to the surface when it is full. However, instead of pulling the whole drill-pipe to the surface, it is nowadays possible to lower a wire-line down the inside of the drill-pipe in order to hook out the core-barrel and pull it to the surface. It is obviously much quicker to reel in a wire than to pull the whole string of drill-pipe from the hole. A similar process has been devised to change the rock bit itself. The retractable rock bit breaks down into three, so that the separate parts can slide down the drill-pipe and lock in position when they reach the end of the pipe. This is an ignenious way to solve the problem of the everlasting drilling bit, but although retractable bits have been used in Russia and the United States they have not reached the stage where they can usefully replace the standard bit.

The Mohole Project

I think it will be agreed that some research will be needed to determine which of these methods of drilling will be most suitable for our 10-mile hole. If I had to make plans now I would devote the greatest effort to a combination of diamond drill-bits driven by a turbo-drill, using water as circulating fluid, and lowering and raising the drill-pipe with an automatic hydraulic lift. But this does not mean that a better rate of progress could not be obtained, say, by a percussion type of drill. However the 10-mile bore-hole even in the most optimistic estimates will take over a year to drill.

Fig. 4.—"Adma Enterprise" at the site of Umm Shaif No. 2 well drilled in the Persian Gulf by Abu Dhabi Marine Areas Ltd.

Part of the useful information from the boring will be in the form of the rock samples that are brought to the surface in the form of chippings and as cores. Further tests of the rock properties *in situ* can be made by lowering instruments specially designed for logging oil-wells. Standard methods can be used for measuring the temperature, electrical conductivity and radioactivity of the rock, and for determining the velocity of sound. It is important to obtain these properties of the rock in place, because one school of thought proposes that the observed seismic discontinuity between crust and mantle may be merely an effect of temperature and pressure which cause a phase change in the material of which the rock is composed. If this view is correct an examination of the rock itself at the surface may not be sufficient to show that the discontinuity has been reached.

I mentioned earlier that the shortest path through the earth's crust was via the oceans, and it is in the oceans that the fairly definite proposals of the United States Mohole project are planned. Many bore-holes in shallow water have been drilled from platforms such as the BP rig. The platform is floated into position and then jacked up on four 10-ft. diameter legs, out of reach of the waves. Some quite deep holes have been drilled from a floating ship like the one in Fig. 4. The motion of the vessel is taken up by gimbal systems and by sliding sections in the drill pipe, so that drilling can proceed except in very rough weather. Quite a large sideways movement of the ship would be allowed by the flexibility of the pipe if the floating ship was used in the open ocean where the water is about 18,000 ft. deep, so that while it would be impracticable to anchor the ship as is the practice in shallow water, it would be possible to maintain its position relative to anchored marker buoys using tugs or the ship's engines. It will be important, of course, to choose a locality which is favoured by good weather, and to obtain good meterological forecasts when dangerous storms are impending.

Fig. 5.—B.P. Exploration Company drilling at Eakring—1955.
Tool service fitter inspecting Tri-cone rock bits.

The drill-pipe is usually guided in and out of the hole by running it in a steel casing which is supported by the ship. It would be impossible to locate the hole three miles below on the sea-bed after removing the drill-pipe to change the bit unless casing were used, although it has been suggested that a wire connected to a funnel-shaped entrance at the sea-bed might be adequate. If any form of everlasting drill bit could be perfected this extra complication could be dispensed with, and then the deep water method

Fig. 6.—Inside the derrick at Well B.102, Persia—c. 1925.

would appear to be a most promising way of achieving the Mohole project. The actual thickness of rock to be drilled will be less than has already been achieved on land, but of course, most of it will be much tougher rock than we normally have to deal with.

One of the benefits to be gained from the Mohole project will be an increased interest in the research aspect of making holes in rock formations. I would like to quote from a recent comprehensive account of drilling techniques by Mr. L. W. Ledgerwood, Jr.: 'From this review of industry's efforts to cut drilling costs through tool-development programmes, it appears that industry may be approaching the point of diminishing returns in equipment developments aimed at preconceived end results. . . . Therefore, it appears that industry's problem is not a development problem, but a research problem.' What we need, in fact, are fundamental thoughts and experiments on the processes of rock failure rather than on new developments of old ideas, and the stimulus for this work could well be provided by the attempts to drill through the earth's crust. A new group of scientists and engineers will be introduced to drilling, and they will be spurred on by their own scientific curiosity which in any mind is a much more powerful incentive to invention than is the fulfilling of a specific staff requirement. A long time ago the mechanical aspects of the steam engine had been brought to perfection by great men like Smeaton, but it was a simple laboratory —or should I say kitchen—experiment that revolutionised the efficiency by realising the importance of a condenser.

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SOCIAL ASPECTS OF THE NEW PATTERNS OF DISEASE: THE ROLE OF THE FAMILY DOCTOR

By **Prof. E. M. BACKETT** *Department of Social Medicine, University of Aberdeen*

With the new patterns of disease in Western societies, and particularly with the emergence of the *chronic* diseases, such as heart disease, cancer, peptic ulcer and bronchitis, of accidents (especially motor vehicle accidents), and of the multiple effects of radiation, as the characteristic and newly important threats to the Public Health, there has come the possibility of a new and different sort of medical care. In this paper I shall mention *first* the nature of the changes in the disease pattern, *next*, some of the types of problem which may arise, and finally I shall emphasise one or two problems of medical care which I personally feel are important, and where doctors may need the help of their sociological colleagues. This new approach is *preventive* in attitude (though the borderline between prevention and very early treatment is rapidly becoming meaningless). However, it is not preventive medicine in the 'water and milk', 'drains and smells' manner of the environmental control era (though these controls are still of vital importance). Rather is it preventive in the sense of using our growing epidemiological knowledge accurately to define vulnerable groups, families and individuals in our population and of manipulating their personal and social environment to prevent disease. But the differences between the old and the new preventive medicine are more striking than they seem at first sight. These days (and at long last) we all accept the necessity for clean milk and the quality control of food, for example, without demur. These controls are satisfyingly impersonal. But if we try to advocate changes in the individual and family dietary customs of our patients, their leisure pursuits, or to change one of the many minor addictions to which we are all prone, we are in trouble. For some of us that trouble is made subtly worse by a feeling that we may have no right to meddle in these personal matters and that our techniques, if we do, are sociologically naïve. Yet, the future General Practitioner has no choice—he *must* meddle, and his meddling must be increasingly personal, for it seems likely that before long our so-called 'new diseases' will offer as much of a threat to life and happiness as did some of the epidemics of the nineteenth century. And, since many of these diseases have their *origins* in our changing ways of living, a tolerable amount of meddling may help to prevent them.

Certain striking trends in disease pattern are well known; our new pandemic of cancer of the lung, for example, which will soon be one of the most common—as well as the most unpleasant—ways of dying. The rapidly growing number of middle-class, middle-aged males who are dying after one or two coronary thromboses. Or those who retire to bed for two to three weeks every six months to nurse a duodenal ulcer—an ulcer which threatens *life* less and less, but middle-aged health more and more. Or the mounting figures of leukaemia, part at least of which represents a real and serious increase in this type of cancer. Another is the motor vehicle accident, which, in spite of its good record to date, is now about to become a major threat again. These are the headlines, as it were, of our new diseases. They gain prominence not only from their increasing threat, but also from the fact that they remain high and dry as the infections disappear. Some of the most serious of these infections are becoming little more than names in textbooks, where only one generation ago they were among what my students call 'the pick of the pops'. Tuberculosis, diphtheria, scarlet fever and measles, though still potentially dangerous (and therefore to be guarded against), are

becoming, in Western societies at least, much less important. With their decline we can suddenly see the enormity of our *chronic bronchitis problem* (25 million man-days lost per year, and thousands of deaths) and of our *cancer problem* (at least 100,000 deaths per year) and the significance of chronic but not always fatal diseases like diabetes, multiple sclerosis and some of the more recently resistant bacteria as well as viruses. We see, too, the useless (though fortunately small) waste of foetal and neonatal life and the few remaining preventable maternal deaths in a new context: the context of a society which, perhaps unlike all previous societies, does not *expect* illness and death, which thinks of health and happiness as its *right* and suspects that when it is unhappy it may well be mentally sick and in need of psychiatric care.

The main features of our changing diseases can be summarised in this way: first, *the vulnerable age groups* are shifting. Young people are no longer ill. In fact the older children and adolescents have virtually disappeared from the doctor's surgery. There is increasing emphasis on the *intra-uterine* child and the neonate, rather than the infant and toddler. Then there is the new interest in the elderly, and above all a growing anxiety about the middle-aged. *The sex ratios*, too, are changing, and the new diseases are increasingly selective of males. Almost all through life mortality figures at least suggest that the male is now truly the weaker sex and the continuing decline in female mortality as a result of safer child-bearing, the new accessibility of some female cancers and the comparative immunity of women from the major scourges now attacking the middle-aged male, will accentuate this trend.

Next, the type of disease is changing (and inevitably, our attitude towards it). For example, infectious diseases were often spectacular and explosive; cases occurred near one another; a thousand or so deaths in a small community had the impact of disaster, while the same number of deaths spread over the whole country—motor vehicle or coronary deaths, for example,—would hardly carry a danger signal strong enough to promote social action.

Next there is *the duration of illness*. Most of our new diseases are chronic, slow moving, processes which may take many symptomless years to develop. For example, the arterial scars which perhaps are associated with our epidemic of coronary deaths in late middle age are visible to the naked eye in the arteries of healthy young men. The cancer of the lung, which is by now our most serious cancer, may have started fifteen or twenty comparatively healthy years prior to the first symptom of the disease, and the men now dying of chronic bronchitis (so characteristically an English and a working-class disease) may well be reflecting not only their smoking habits and the air pollution of the cities in which they have lived, but also the shorter convalescence enforced on working-class families by the tough economic pressures of the hungry thirties. It is this long duration of the degenerative diseases and of cancer which is doing most to force us to change our methods of medical care.

Finally, we can say that with a few exceptions our new threats to health are, by their very nature, somewhat *less* likely to respond to curative medicine than the diseases of the past. The brain damage of an injured motorist is largely irreversible, however good the surgeon. The treatment of patients exposed to radiation is likely to remain disappointing at least for some time. Brilliant chest surgery has altered the five-year survival rate of lung cancer patients by only a very small amount. Again, wonderful advances in anti-coagulants and antibiotics have altered the outlook in heart disease and chronic bronchitis by only a very little, for *in all these diseases tissue changes are of great age*. The outlook may have been just as black in the past and for diseases which are now very easily cured, so the point is not a strong one. However, thanks to the impeccable epidemiology of people like Doll, Hill, Case and Morris, the *prevention* of many cancers, and some other chronic diseases, has become possible *long before* the disease itself is fully understood. For example, many skin and industrial cancers have disappeared as a result of the removal of carcinogenic substances from the industrial process years before the fundamental pathology became clear.

Thus, in the face of our new diseases, *prevention* acquires a new urgency and the future family doctor will be forced increasingly to switch his attention from sick people to the habits and behaviour of healthy people *many years prior* to the clinical onset of illness.

So here, crudely, is the problem: Most people

who feel ill *seek* medical care, take advice and have a rather special relationship with their doctors. Healthy people, on the other hand, are unlikely to be particularly impressed by talk of a disease which *may* come in twenty years' time. Their attitude to doctors who seek to change their behaviour, and thus to promote their future health is one of polite disinterest.

There are, of course, countless other social problems associated with our changing patterns of disease and death. Some arise only as the *demographic consequences* of the changes begin to be felt. Others are forced upon us with each *review of social policy*, in health matters, in insurance, and even in such apparently peripheral areas as road building and the siting of power stations. *With the increasing survival of those born unfit and handicapped* (which is an interesting though fortunately not yet a particularly important consequence of the march of medical science), we are likely to become more than ever involved in their educational and welfare problems. And in the future other highly complicated social-medical problems such as that of genetic counselling are sure to arise.

And so the list of new problems can be extended. But those associated with the future of medical care, particularly in general practice, are my immediate concern. The problems involved are major ones for the patients, for the planners and administrators of our health service, and, above all, for the family doctor. They arise from this situation: it is now possible, and I believe desirable, for a major part of the General Practitioner's job to become the highly scientific supervision of *healthy* people. Such a statement does not sound particularly surprising, nor is the cliché 'prevention is better than cure' particularly new. However, at the moment rather over 90 per cent of the family doctor's work is curative, dealing only with established disease. If even 50 per cent of his work were to be concerned mainly with *healthy* people, rather than the sick, this would amount to a revolutionary change. Such a change has been made *necessary* by the changes in disease pattern and *possible* by a growing knowledge of the reasons for differences in the vulnerability of different age, sex and social groups. Thus the General Practitioner who knows well how his patients live will be able to define with increasing accuracy who amongst them is likely to become ill. In short, the way is now clear for the General Practitioner's job to become more and more that of a highly skilled diagnostician in a new field, not only of disease, but of differences in ways of living and so of the vulnerability of his patients. It may well be that he alone—because of his contact with the family—is the only health worker able to observe and control the social and other aspects of behaviour which we know are the precursors of disease. *In addition* to this change of approach, the doctor now has a growing armoury of screening devices and simple tests by which he can pick the already ill from among the vulnerable people in his practice, and so make increasingly early diagnoses of disease. Many of our chronic diseases, for which palliative treatment only is possible when they finally show themselves, *could* be cured if picked up years before when the patient was apparently fit and well. A pre-requisite, therefore, of successful early diagnosis with the new screening tests is that the patient should be seen when he is still feeling fit—that is before he would *normally* seek medical care, and long before serious symptoms arise.

I would like to illustrate these notions by reference to one of the more unpleasant cancers—cancer of the uterine cervix. Epidemiologically speaking, this cancer is well described. We know a lot about what sort of people get it—but, of course, very little indeed about exactly *why* they get it. The vulnerable person is, broadly speaking, the multiparous woman who married and bore her children at an early age and who comes from one of the poorer socio-economic classes. When she develops her cancer it remains localised for a long time, probably for years, and gives no sign of its presence. Through a simple technological advance (in staining and microscopy) it has now become possible to make a very early diagnosis of the developing growth. We are told that treatment at this stage is relatively easy, safe and surprisingly sure. In the past even good epidemiological understanding of this condition was of little help to the family doctor if he had to wait for the disease to present itself. By then it was often too late. It is the *combination* of good epidemiology (which tells him where the disease will arise—so that he need not test all the women in his practice), and this simple, early test, which has suddenly given the General Practitioner the power if not to eradicate

the disease, then at least drastically to reduce it in his practice. But, at once we are back at the same problems as before. How is it possible to persuade apparently completely healthy women who belong to the vulnerable age, parity and social group to seek medical care long before they feel ill: and how can we fit this approach into a service based almost completely upon curative medicine.

Similar simple tests which can be used for screening apparently healthy populations for all manner of different diseases are rapidly increasing in number and accuracy. Already more or less accurate and very early diagnoses (that is, long before the patient is conscious of illness), can be made in some chest conditions, a few cardio-vascular disorders, some renal diseases, and an assortment of hereditary metabolic upsets, mild diabetes and at least one cause of blindness.

In this way it seems that our new diseases are themselves forcing us into a new sort of medical care. But I suspect that this new medical care may in turn need a new and rather different sort of doctor to apply it. With the exception of one or two schools, the present education of the doctor is, of course, entirely a hopsital education and 'the hospital culture' leaves its imprint upon his later work. His interests are inevitably in *curative* medicine where modern biochemistry is paying such wonderful dividends with orthodox disease—and, of course, there is plenty of curative work for the family doctor to do. So much so, in fact, that the practitioner of today may not have enough time even to practice good curative medicine with anything but a very small practice, let alone have time for the early diagnostic and preventive work I have mentioned. *Willinck*, in his famous report, has said we have too many doctors in this country, and possibly we have, for the sort of nineteenth-century medicine he and his committee were prepared to tolerate. But our changing disease pattern is likely to demand something more up-to-date and for this much more time is needed.

There are other difficulties too. For example, it is almost written into the doctor's code of conduct that he should play a waiting role—to begin with, at least, the initiative must be with the patient. To alter this balance, it is said, would 'strike at the doctor/patient relationship'. Whether such generalisations are true or false, it is undoubtedly difficult for a man with this training and background to write, for example, to all the healthy adults on his list inviting them to undergo even the simplest screening tests. It would be even more difficult completely to re-organise his practice so that at least half his time was spent in this way.

There is yet another problem: how can the future family doctor 'screen' the vulnerable people on his list, offer his genetic counsel, advise effectively on diet, exercise and leisure, or even measure the blood pressure of his middle-aged men, without creating, not a healthy practice, but a mass neurosis? We have seen a suggestion of this type of neurosis following the indiscriminate 'check-up' campaigns, the savage cancer films, and the commercial exploitation of anxiety which has occasionally been a feature of so-called health education elsewhere. However, our small experience of studies over here, and the much wider experience of calmly and well-run studies of community health (such as that at Framingham in the U.S.A.) suggest that these dangers can be avoided. Nevertheless, they remain an important threat and it may be that we shall lose more than we will gain. The prevention of heart disease, for example, may save the lives of mentally healthy men by converting them into cardiac neurotics! Certainly the transition to some sort of health supervision in general practice will be eased, and this neurosis avoided, if the medical sophistication of the population continues at the rate which is at present reported. It was a patient, not a doctor, who drew my attention to the fact that in walking down the street one rarely, if ever, sees an *old* fat man! I had no difficulty in convincing this patient of the importance of obesity, for he had noticed himself that the thin survive.

Changes in disease patterns must always have given rise to new social problems—our current transition from the infections to chronic degenerative disease is no exception. These problems are, of course, the result of a complex interaction of factors—new diseases are only one of them. I have mentioned a series of problems which I hope medicine and society will at least consider during the next ten years or so. Among them, perhaps the changing role of the general practitioner is the most intriguing. Clearly the family doctor must in future be prepared to make himself something of a nuisance to his patients. But if he does, will they take any notice of him—and why should they anyway?

I believe that we can only find the answers to these problems by painstaking study and I would like to see them tackled first, through operational research (we in Scotland hope to try out some new approaches to general practice ourselves before long) and through changes in the teaching of medical students. (These I have already tried to introduce in my department.) In both these fields I would like to work with my sociological colleagues, for if the future doctor is to challenge these new diseases at all, he must not only be a first-class epidemiologist, but he must be familiar with society and with the ways of living of the families in his practice, in a much more sophisticated way than he is at the moment.

LOOKING AT science

A very important aspect of the development programme of the British Association is the presentation of science to young people. Here is a field in which visual presentation can play an important part. Dr. D. C. Martin, Assistant Secretary of the Royal Society, a Council Member of the B.A. and a member of the Association's Scientific Film Committee, when addressing the Scientific Film Association in January, 1959, said:

I must make it clear that the B.A. has no wish to become yet another body dabbling in visual aids activities. Its programme is intended to be complementary to the work of existing agencies and if successful should lead to a greater demand for their services.

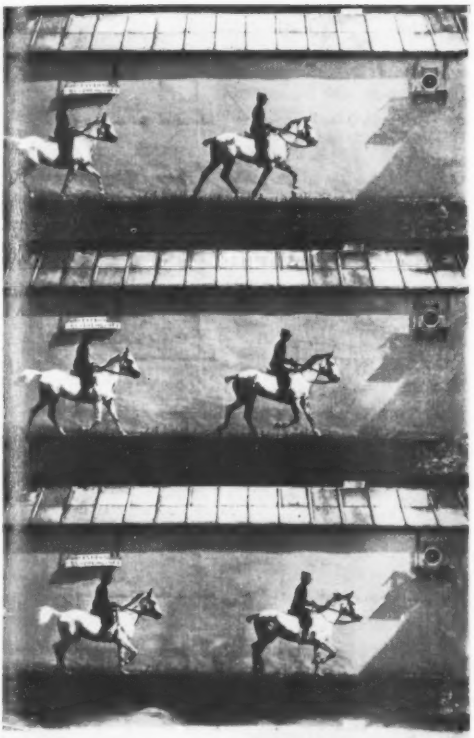
Activities since then have been based on this policy. Visual aids have been used extensively in the last two years in a variety of ways. Scientific film programmes have become an important part of the activities at the Annual Meeting, and attracted record attendances at Cardiff. Cardiff also provided the occasion for a number of exhibitions on such subjects as 'World Food and Population', 'Silicones', 'The World of Oil', 'Mathematics', and for a School Science Exhibition, which included much visual material. At a meeting which was supported by 4100 members all these events attracted large audiences.

Visual aids play an important part in curricular and extra-curricular education, and the Association (as reported briefly in the last issue) has initiated two important projects in the last eighteen months, which encourage a wider use of visual aids in both these fields.

In the Autumn of 1959, the B.A. arranged a series of receptions for teachers of Chemistry, Physics and Biology. These were made possible by the generous help and hospitality of I.C.I. Mullard and Unilever. From sixty to ninety guests attended each reception. A programme of films was shown, which included productions sponsored by the host firm and films on the subject of the evening from other sources. A display of appropriate charts, filmstrips, and other visual aids, together with distributors' catalogues, was also arranged. These receptions proved so successful that a further series was organised in the new year, and a more ambitious series started last autumn. To date, in London, three receptions have been arranged in co-operation with Unilever; two with Mullards; two with I.C.I., one with Shell and one with Shell-Mex and B.P.

It was desirable and convenient to begin such an experiment in London, but it was always the Association's long-term objective to arrange such meetings in many parts of the country, once their value had been demonstrated. An important new development, therefore, was the organisation of a reception at the Dyestuffs Division of I.C.I. in Manchester, followed by a further reception with I.C.I. Billingham Division. At the time of going to press further receptions outside London are being arranged with the National Coal Board's Durham Division, and West Midlands Division, with Unilever (Merseyside) Limited, and with British Oil & Cake Mills, Glasgow.

Teachers of many subjects (biology, chemistry, general science, physics, technical education) have thus been introduced to a wide range of visual material in their own field. Questionnaires were distributed to those attending four of these receptions, and the response was overwhelmingly enthusiastic. At no reception has more than a small minority of the teachers present previously seen



Two mounted horsemen. A study obtained by the French physiologist, E. J. MAREY, using his 'chronophotographic camera' (invented in 1887) which was the forerunner of all modern cine cameras.

any one of the films shown, and at one reception none of the four films screened had previously been seen by any one present, although two of them had been in distribution for two years.

The reactions of the teachers to the films shown emphasises the problems that sponsors and producers face in making films for education. A film which received an enthusiastic comment from one teacher would be dismissed by another teacher from the same type of school. Thus one film on the principles of X-rays was considered by one teacher to be Good. 'Would be useful for teaching advanced level physics. Probably too difficult for O levels, although it might be shown at a Science Society Meeting,' and another commented tersely —'Well treated; good for 6th form'. In contrast one teacher asked, 'An attractive film, although I am not quite sure who it is for? Parts were too elementary for the 6th form, but other parts too advanced for lower forms. Perhaps useful for revision, and non-science 6th form for general interest.'

A Czechoslovak popular science film exposition of Einstein's theory of relativity also produced contradictory reactions. 'Good entertainment and stimulating. Extra-curricular but would be useful in a science for art students course.' 'A brilliant film of great value to schools at advanced levels.' 'Too popular. It would be enjoyed without the audience realising its implications.'

Because teachers are very busy people, and because the number of visual aids and their sources of origin are legion, it is very difficult for even the most enthusiastic to keep abreast of the latest available material, and there is no doubt that this type of reception is both introducing some teachers to the possibilities of using visual aids in their subjects, as well as helping the enthusiastic user of such aids to keep his information up-to-date.

Even where a teacher is very keen on using films in school he has still many problems to face in arranging for the presentation of science on film to varied school audiences. Another project, initiated by the Aberdeen Area Committee and enthusiastically adopted elsewhere, offers one approach to this problem. The B.A. selects and orders a programme of science films deliberately intended to be comprehensive in subject matter and lively and imaginative in film treatment. This programme is then shown to school children in a selected area, either by being passed from school to school, or by children from different schools attending performances at some convenient centre. Thus in Aberdeen eighteen Secondary schools of both types have now shown two programmes to 10,000 children in each case; whilst the West Midlands Area Committee arranged, in co-operation with Coventry Education Authority, ten screenings of a science film programme at the Technical College, which were attended by 5000 children from Secondary Modern Schools. Similar projects are being arranged in Herefordshire, Worcestershire, Worcester City and Liverpool, and similar projects are being considered in several other centres.

Such a programme of films is not intended to teach children science, but is a means of providing scientific background information and stimulating interest in the world around them. Nevertheless if the programme is well presented children will learn something from it, as this comment from an 11-year-old on part of a film programme suggests. It was written the week following the screening of a science film programme to the whole school:

The first film was about the origin of coal. It showed how coal was formed by the forests millions of years ago. The trees grew in a swamp and they gradually fell and all the wood together became what we call peat. Most of Britain at this time was a large swamp and today we have coal fields in Fife, the Midlands of England and Wales. Due to upheavals on the earth's surface the peat was squashed and made into a very dense peat which was coal. It also showed how coal mines were dug. On the whole it was quite good and the pictures inside the actual mine and of the machinery kept most people interested. The second film was about the motor car and it showed the bare essentials of its mechanisms. It was made in cartoon form and I think this kept the interest in it and made it very enjoyable.

A classmate was very candid in his observations:

The first film I thought was very interesting. In this film it explained how coal was formed and how it was dug up. It was shown in a simple form and it was easily understood. The second film, which I liked best of all, was about the motor car. Again the film was shown in a simple form but it had also a dash of comedy which made it even more interesting.

The third film I did not like at all. This film was about Spring. This film did not catch my interest in any way and was altogether too drab.

Presenting a carefully selected programme of this kind has definite advantages. A programme of about five films can be chosen, selected from perhaps thirty times that number—involving detailed pre-viewing of a kind the average teacher would find impossible. Moreover these films reach an audience infinitely larger than that which could be obtained by orthodox methods of library distribution. The average library allows ten days per film booking. In thirty days a programme booked by the British Association was screened in eighteen schools to audiences totalling ten thousand. In the receptions held to date about one thousand teachers have seen specialised films and other visual aids —many unknown to them hitherto.

Thus these new developments are creating new audiences and helping, in a very practical way, to complement the work of other organisations.

SOME ASPECTS OF INVESTMENT IN UNDER-DEVELOPED COUNTRIES

By D. H. BUCKLE *Manager, Information Dept., The United Africa Company Limited.*

It may be a truism, but it must be stated that there are too many investment projects chasing too little money. Funds are needed not only to finance industrial expansion but also to develop fully natural resources of all kinds, to set up and to maintain social services, and to foster the growth of the public utilities without which no country can hope to prosper. Both public and private investment are sorely needed, and it thus becomes apparent that some form of choice must be exercised. What are the chief needs of the under-developed countries of today? How can these needs best be met? How can under-developed countries best attract investment funds?

Needs of Under-developed Countries

The most important needs are undoubtedly those of adequate food and enhanced standards of health. The vicious circle of under-nourishment, poor health, low productivity, lack of money with which to buy better or even sufficient food, consequent under-nourishment and so on *ad infinitum* is well enough known to need no comment here. The immense amount of research into health and hygiene and the expenditure of large sums of money and an infinity of patient endeavour have resulted in the lowering of mortality rates and the prolongation of human life; but there has been no parallel increase in food production.

The problem of increasing population throughout Africa is a very real one. There have been difficulties in conducting accurate censuses, but the figures for Ghana alone show that, in the years from 1948 to 1960, the population there increased from 4,118,000 to 6,691,000. Assuming these figures to be reasonably accurate, they suggest an annual rate of growth of around 4 per cent, and it is estimated that in 20 years' time the population of Ghana will have doubled. If a comparable increase occurs over the whole of Africa with its population of some 200,000,000, a means of feeding them must be found. How is this to be done? Many millions are at present suffering from inadequate diets, and any increase in food production, so far from supporting increased numbers, will hardly suffice the present population.

Future increases in food production will depend upon the use to which agricultural land is put. Contrary to widespread popular belief, there are few if any areas of potential agricultural land lying idle in Africa today. The problem is rather one of increasing production and yield over areas already in use. In Africa, however, the social pattern is geared very much to community land ownership; and family wealth and prestige may be reckoned in terms of numbers, not even quality, of livestock. Family and tribal unity is totally dislocated when modern, Westernised methods of agriculture are introduced in an attempt to improve productivity. Over large areas of Africa the method of farming is one of shifting cultivation, whereby areas of land are left idle for periods of up to ten years while the inhabitants move to cultivate elsewhere. Such a system ensures the regeneration of the land; but pressure of population is already reducing the fallow periods and continuous cropping without the addition of costly fertilisers, and the adoption of intensified agricultural methods results in soil exhaustion and erosion. Recent land experiments in Kenya have, it is true, resulted in increasing productivity and have curbed property fragmentation amongst other members upon the death of the head of the family, but it is plain that it is not possible for large families to continue to exist off the land as they have done in the past.

Fig. 1.—The two largest timber enterprises in Africa are found in Ghana and Nigeria, and afford an example of how capital and technical and management skills can turn a hitherto unused natural resource into a material asset. Mechanised handling methods are used whenever possible in transporting the logs to the saw mills, where they are cut up, processed, and then in many cases exported.

Meeting these Needs

In the face of an increasing population which cannot hope to be fed even if existing methods of agriculture are intensified, it is clear that further steps must be taken consistent with the necessary social reforms.

Education is perhaps the most urgent factor. It is chiefly this which renders technical and scientific progress possible, and it is only by education and a growing awareness of the outside world that a closely-knit and backward agricultural community can be enabled to accept social and economic changes. Above all, it is only education that can fill the gap left by the breaking down of old customs and beliefs.

Once the necessity for change has been acknowledged, co-operation is to be expected from the people. In the last half century, great strides have been taken throughout Africa to develop economically the natural resources such as agricultural land, mineral wealth and water power, with which the Continent has been endowed.

As examples of this, the timber industries in Nigeria and Ghana, hardly extant fifty years ago, now at the same time both conserve and control forest resources and also contribute 4 per cent and 12 per cent by value respectively of total exports (1959 figures). Cocoa farming in Ghana, from which over 14½ per cent of the population earn a direct living, contributed some £70 million, over 60 per cent of the country's exports by value, in 1959. Nigeria's palm kernel and palm oil industries have been developed over the years by the introduc-

tion of up-to-date machinery and marketing methods until today they account for no less than 25 per cent by value of the country's exports. In the Congo Republic (formerly Belgian), mining has been developed until under normal political conditions it contributes over 20 per cent of the national income and minerals make up over half of the total export earnings.

While it is clear that much has been done to develop Africa's natural resources, there is still room for improvement. It is disquieting but true that in Central Africa and in East Africa Government expenditure on agriculture lags far behind expenditure on secondary industries. Although a purely agriculturally-based economy satisfies completely neither the increasing material needs nor the mental aspirations of an expanding population, the full development of natural assets is essential if the economy is to be broadly based. Once this development has been begun, a surplus of produce is created which leads to an increase of wealth and a growing consumer demand for all kinds of goods, from the purely frivolous to the strictly utilitarian. This demand can only be met by industrialisation, which also affords the means by which those displaced from agriculture can be absorbed.

What form is this industrialisation to take? Investment in the public utilities such as water, power and transport provide the framework within which is set up a fully-diversified economy. There are possibilities for investment in the processing of locally grown produce. Examples of this are the way in which palm oil and timber are processed in West Africa, and in the canning of meat and milk in East Africa.

In West Africa, much money has already been spent on mining and such industries as building and construction companies, cement works, cold storage for foodstuffs, motor and bicycle assembly plants, plastics, textiles and bedding factories, and breweries. In addition, the operations of trading companies have stimulated the demand for goods of all kinds and have thus provided the incentive, as well as the financial means, for the setting up of indigenous businesses.

Obtaining the Money

All this commercial and industrial activity presupposes the influx of large amounts of capital,

Fig. 2.—Plastics are but one of the many new industries recently set up in West Africa, whereby imported capital and technical skills are made available for the employment of indigenous inhabitants. In this photograph, polythene granules are being emptied into a hopper at the start of the process resulting in the manufacture of plastic tubing.

either publicly owned or private. The social sector of the economy is, generally speaking, financed from public money. Money for education, medical services, the utilities, and such large undertakings as the projected Volta River Scheme in Ghana, the eventual cost of which has been reckoned at some £125 million, can only be found from Government sources or from international bodies such as the World Bank.

Funds for investment in commerce and industry are found mainly from private sources. In certain cases, however, Government also participates, partly in order to increase the sum of money available but also because it wishes to share more directly in any eventual profits that may be made.

It thus becomes a matter of concern for Government to be able to attract private investment. In this connection, extracts from a recent statement put out by Dr. M. I. Okpara, Premier of the Eastern Region of Nigeria and National President of the National Council of Nigeria and the Cameroons, give an indication of the importance attached to the continuance of private investment:

There are many roads to socialism and the N.C.N.C. has definitely not chosen the road of

Fig. 3.—An example of the economic utilisation of natural resources. Here, dry palm nuts are being cracked by a power driven cracking machine, while screening serves to remove dust, small pieces of shell and other impurities before kernel separation.

nationalisation. The greatest need of Nigeria today . . . is capital to develop our potentially rich national resources. Since there is very little capital in Nigeria, most of this much needed capital must come from outside . . . We as a party and as a Government are committed to making the conditions for outside capital so favourable that it will help us to raise the standard of living of our people quickly; and to this task we have dedicated ourselves.

What conditions must be present before private investors can be induced to make money available to under-developed countries? First, the project concerned must be as commercially attractive as possible. Private investors are extremely vulnerable to business risks, and it must not be forgotten that even the largest companies owe a duty to their shareholders not to hazard their money unnecessarily.

If a project has proved to be a commercial success, the resultant profits must be freely transferable to the country of origin. In the same way in which an individual investing £5 in the Post Office expects not only to receive his interest but also to recover his capital whenever he wants it, so a business concern must be able to receive its profit and also, if it so chooses, repatriate its capital. Unless these conditions are met, the overseas private investor will place capital elsewhere.

Political stability, or its absence, is also a major factor to be taken into consideration. Is the Government of the country so constituted that private commercial activity will be encouraged? In spite of temptations to give way to extremist nationalistic feeling, Governments of newly-emergent African states have constantly reiterated the substance of Dr. Okpara's statement quoted earlier, and it is clear that interference with business activities would result in a substantially reduced inflow of capital.

More positive inducements are also held out by Governments to attract would-be investors. Temporary relief from company taxation, and generous depreciation allowances, secure a breathing space for new industries and businesses. Customs duties can be reduced or abolished altogether on imported raw materials and capital equipment. Measures are sometimes taken to impose heavier duties on imported articles which compete with those locally manufactured.

It is noteworthy that ploughed-back profits have been in the past the major source of foreign private investment. To ensure the continuance of this state of affairs, confidence must be maintained between Government and investor. The best way in which to achieve this is for both parties to bear in mind their fundamental aims. Both have a vital stake in the country, and are concerned to promote its prosperity and well-being. Although their motives for this may differ, their objects, so far from conflicting, are bound always to coincide.

BRITISH ASSOCIATION NEWS

Annual Meeting, 1961

The 123rd Annual Meeting of the British Association will be held in Norwich this year from August 30 to September 6, and, on a site where man has dwelt consistently since prehistoric times, there is a certain fitness that the Association's President, Sir Wilfrid Le Gros Clark, F.R.S., should be one of the world's outstanding students of the ancestry of Man. Sir Wilfrid, who is a Fellow of the Royal Society, has been Professor of Anatomy at Oxford University since 1934 and his research has ranged widely in the fields of anatomy, zoology and human palaeontology.

The Association has met in Norwich twice before —in 1868 and 1935—and the beauty of the setting, the wealth of scientific, historical and antiquarian interest and the warm welcome of the people of Norwich, now eagerly looking forward to the status and responsibilities of a University City, promise that 1961 will rival previous years. Topics in the scientific programme will include geophysics, chemistry and spectroscopy, petrology, the origin of the Broads (to name but one example of the considerable local interest), dating Man's emergence, aspects of the current economic situation, world communications, the sensory nervous system, the revolution in agriculture, teaching machines. There will be two outstanding Evening Discourses for members and their friends, a special programme for young people and a continuous showing of scientific films.

Further details of the programme and essential information on registration for the Meeting and booking of accommodation will be contained in a preliminary programme, to be issued to all members early in April. Those wishing to obtain a copy or any further information about the Meeting should apply to The Secretary, British Association for the Advancement of Science, 18 Adam Street, London, W.C.2.

Kelvin, Darwin and Lister Lectures

Despite a small entry, the academic standing of the three candidates chosen to deliver the Kelvin, Darwin and Lister Lectures at Norwich this year is strikingly high; though this no more than conforms to the pattern of the two previous years, it can perhaps be taken as an indication of the prestige already enjoyed by these Lectureships (established by Council in 1958 to encourage young research scientists to report in non-specialist language, especially to scientific colleagues in other disciplines, on the nature and significance of their work) and of the importance of the Association's initiative in this field.

The Kelvin Lecturer, D. J. E. Ingram, is Professor of Physics at the University College of North Staffordshire. His postgraduate research at the Clarendon Laboratory, Oxford, was carried out under the supervision of the late Lord Cherwell and Dr. B. Bleaney, and in the last eight years, with his group at Southampton University, he has made a number of valuable contributions to the field of electron spin resonance, notably in applications to free radicals, and to the environment of iron atoms in large molecules. His Kelvin lecture is likely to deal with some aspect of investigations in the microwave region of the electromagnetic spectrum and he has had considerable experience of just this kind of presentation, both during the last year at Keele and at various international conferences in the United States and Europe.

'The importance of borderline sciences' was one

of the provisional titles submitted by Dr. Judith Milledge, Lecturer in Crystallography at University College, London, and it was the sense of the potential value of studies in those areas where disciplines meet that encouraged the Council to appoint a crystallographer to the Darwin Lecture. Coming as she does from South Africa, members who heard Dr. Milledge at the Glasgow Meeting in 1958 may have felt there was a certain suitability about the paper she read at the Meeting on 'Diamonds in the sky'; her Darwin Lecture at Norwich will most assuredly reflect once again the vigour and clarity of her ideas.

Dr. R. G. Lipsey, the Lister Lecturer, strengthens the Commonwealth representation among the successful candidates this year. At present a Reader in Economics in London University, he is a B.A. of British Columbia and an M.A. of Toronto, where he was a lecturer for two years. He has written and spoken in the field of his work —pure economic theory and the relation between economic theory and empirical observations—and he is likely to develop his Lister Lecture on some such lines as these.

Area Committee News

The programmes of the first three Area Committees to be established—Newcastle, Tees-side and Durham—continue to develop. From September 1 to the middle of December, Tees-side gave 73 lectures, and Newcastle 50. The latest figures for Durham are not available at the time of writing, but they are fully keeping pace. It has been said before, but it will bear repeating: programmes such as these, organised year after year, cannot fail to have a major impact on the problems to meet which Area Committees were established.

The West Midlands Committee programme is developing at a similar pace. At the end of the summer, after sending out their 1961 brochure, they were receiving requests for speakers at the rate of six a day. Fortunately the stream then slackened a little, but the indications are that by the end of the season they will have given between 150 and 200 lectures. The West Riding and East Midlands Committees have sent out their brochures and are developing their first full programmes of lectures.

The Cornwall Committee arranged the second of their large public meetings in Truro, when Mr. W. G. Busbridge of the Wantage Laboratories of the U.K. Atomic Energy Authority lectured on 'Fission, Fusion and the Future' to an audience of between 700 and 800 at the Town Hall, Truro.

Council of Europe Conference

The Association was asked to send a representative as part of the British delegation to the Council of Europe (Partial Agreement) Youth Sub-Committee conference at Liège in November, on means of encouraging scientific pursuits among young persons. There were delegations from France, Italy, Western Germany and Holland, as well as Belgium and the United Kingdom. The field to be studied was so wide that the members of the conference could only regard their deliberations as exploratory for a larger conference to be held later. In view of the Association's obligations for the social and international relations of science, it is gratifying that at least three of the suggestions put forward by the Association's representative were considered likely to lead to fruitful international collaboration. One was the Junior British Association type of meeting, and the second the Science Fair project which was described in the last number of *The Advancement of Science*. The third was a recommendation that whenever in any country a suitable event is organised, the opportunity should be given to other countries to send young people. The British Association has given a lead in this, by making arrangements for some 30 young people from Western Europe to attend the Norwich Annual Meeting this year.

Lecture Service

The number of lectures given during the autumn months of 1960 shows an increase of 50 per cent over those of the corresponding period of 1959; although there is a steady demand from many types of audiences, this particular increase can be attributed to the growing number of requests for lectures received from schools and from industrial audiences. The subjects selected by the schools have ranged over a wide field of science and those chosen by the industrial organisations reflect a special interest in automation, ergonomics, and, recently, in the metric system.

Sufficient time has now elapsed since the formation of the lecture service for a valuable relationship

to be established between those using the service, the lecturers and ourselves. This greatly facilitates a constructive and imaginative use of the lecture service.

The B.A. was asked to invite speakers to take part in several Youth Conferences. These conferences were attended by a cross-section of youth, including science sixth-form grammar-school pupils and boys and girls of the corresponding age group who left school at sixteen. This provides a fruitful meeting point, as those who have been in employment since leaving school, bring a totally different point of view to bear in the discussions following the talks. Dr. W. E. Swinton of the British Museum (Natural History) and Mr. Nigel Calder of the *New Scientist* have taken part in these conferences, and Mr. C. D. Curling of the Physics Department, King's College, London, in a somewhat similar conference for an older age group.

Among the women's organisations, requests have come mainly from local branches. But there is also a demand for lectures for some of the more central events of the various associations. At the Annual Conference of the National Council of Women, Dr. Patricia Scott spoke on food additives, and lectures have been included in residential courses arranged by the Y.W.C.A., and the National Federation of Women's Institutes.

Christmas lectures have been given before large audiences, usually around seven or eight hundred school children. These lectures have been sponsored by local civic societies, natural history societies, and museums in different parts of the country.

Professor E. F. Gale's lecture on 'The Life and Death of a Bacterial Cell', delivered in Birmingham on December 15, was nominated as the British Association 1960 Norman Lockyer Memorial Lecture.

Dr. J. Fremlin of the Physics Department of Birmingham University acted as tutor to a one-day School on nuclear physics, held in the exceptionally fine hall of the new college buildings of the Technical College, Shrewsbury. The school was attended by 250 technical students and sixth-formers, a number of whom came from places as far away as Wellington, Kidderminster, Welshpool and Monmouth. The one-day School with lectures, demonstrations and discussions was brilliantly led by Dr. Fremlin and it is hoped to repeat a similar type of programme in Shrewsbury, which obviously forms a natural centre for a considerable area.

The University Institute of Education at Oxford invited the B.A. to draw up the programme for a conference for science teachers held in Oxford, November 18–19, on the theme 'From Science to Technology'. The President of the British Association, Sir Wilfrid Le Gros Clark, chaired the opening session when the conference was addressed by Sir Ewart Smith speaking on the central theme. Four other speakers took part representing four major industries: Dr. I. J. Faulkner of I.C.I., Billingham, on the Chemical Industry; Dr. H. Kronberger, O.B.E., Director of Research and Developments, Engineering Group, U.K.A.E.A., on the Atomic Energy Industry; Dr. G. D. H. Bell, Director of the Plant Breeding Institute, Cambridge, on Agriculture; and T. A. L. Paton, C.M.G., Sir Alexander Gibb and Partners, on Civil Engineering.

At the request of the Buckinghamshire Education Authority a residential course was arranged for twenty-five science sixth-formers from eight schools in the Slough area. The general title for the week's study was 'Growing Points in Science'. Dr. W. E. Swinton took the opening session on the Monday afternoon, and summed up at the concluding session on Friday morning. As an experiment, instead of dividing the time into a number of sessions, there were three one-day tutors, each of whom planned his own day and illustrated his talks with very fine demonstrations. The tutors were Dr. J. Williams, R.A.E., Farnborough, on aeronautical engineering, 'Aerodynamic Aspects of Short Take-Off Aircraft, Vertical Take-Off Aircraft, and Hovercraft'; Dr. H. R. Allan of Imperial College of Science and Technology on nuclear physics, 'The Uses of Matter'; Dr. N. Symonds, M.R.C., Microbial Genetics Research Unit, on biophysics, 'Physical Aspects of Life'. The week ended with a visit to Harwell. There is little doubt that this pattern for a week's residential course for science sixth-formers is one that may well be adopted on future occasions.

Endeavour Essays

Prizes totalling 100 guineas are offered by Imperial Chemical Industries Limited, publishers of the quarterly scientific review ENDEAVOUR, for

essays submitted on scientific subjects. In addition to the cash prizes, the prizewinners will receive invitations to attend the whole of the British Association meeting at Norwich, from August 30 to September 6, 1961. All expenses will be paid, including travelling expenses within the United Kingdom.

As the primary purposes of these awards are to stimulate younger scientists to take an interest in the work of the British Association and to raise the literary standard of scientific writing, the competition is restricted to those whose twenty-fifth birthday falls on or after June 1, 1961.

FIVE PRIZES WILL BE AWARDED

A first prize of 50 guineas
A second prize of 25 guineas
A third prize or 15 guineas

Two special prizes of 5 guineas each for competitors who have not passed their eighteenth birthday on June 1, 1961.

THE SUBJECTS FOR THE ESSAYS ARE AS FOLLOWS

1 *The Periodic Table: its modern significance*
2 *Meteorology and its possibilities*
3 *Radioastronomy*
4 *Waste: its utilisation and disposal*
5 *The mammalian egg*
6 *Computers and their uses*
7 *The form and structure of leaves*
8 *Photoperiodism*

The essays, which must be in English and typewritten, should not exceed 4000 words in length, and only one entry is permitted from each competitor.

All entries should be addressed to:

The Deputy Secretary,
British Association for the Advancement of Science,
18 Adam Street,
Adelphi,
London, W.C.2,

and the envelope should be clearly marked 'ENDEAVOUR Prize Essay'. The latest date for receipt of entries is June 1, 1961. The essays will be judged by the editor of ENDEAVOUR in consultation with representatives of the British Association. The judges' decision is final, and the right is reserved to withhold all or any of the prizes should no entries of sufficient merit be received. The essays must be submitted without signature. The competitor's full name and address and date of birth should be disclosed in a sealed covering letter attached to the essay and addressed to the Deputy Secretary of the British Association, who will acknowledge all entries. The names will not be disclosed to the judges until after the prizewinning essays have been selected.

Special attention will be paid to the originality of the approach to the subject of the essay, and to syntax and literary style. The competitor's age will also be taken into account. The essay winning the first prize will be published in THE ADVANCEMENT OF SCIENCE.

THE ADVANCEMENT OF SCIENCE

A complete list of Contents for Volume XVII of The Advancement of Science is available and will be supplied to subscribers on request.

SCIENCE COURSES FOR TEACHERS

By **Mrs. HELEN BUNTON** *Homerton College, Cambridge.*

The Physical Sciences Section of the Association of Teachers in Colleges and Departments of Education held its first conference at Furzedown College, London last autumn. It met to consider the problems facing lecturers in Teacher Training Colleges in their work of preparing students as specialist teachers in the Sciences, competent to teach their subjects at least to the 'O' level of the General Certificate of Education, and to study methods of attaining the high standards of achievement desirable to meet the nation's social and educational needs in the immediate future. The guest speaker was Professor G. F. J. Garlick, Professor of Physics in the University of Hull, and his lively ideas and vigorous expression of them provoked some valuable, and often animated discussion.

The Training Colleges are already providing many new laboratories, and the facilities for teaching physics and chemistry in them are expanding materially. Growing out of this was a proper concern for recruitment of students and staff to meet with this new expansion, and the preliminary discussions on policy turned largely on this point. It was felt that far too many Heads, careers staff, and even science teachers in Grammar schools had little or no knowledge of these courses, and at interview candidates often echoed their school's advice that if they wanted to study the sciences much above 'A' level they should go to the universities. It was agreed that a suitable approach should be made to the schools to provide them with accurate information about the science courses in Training Colleges.

Difficulties in recruitment of suitable staff was being felt in many quarters, and it was thought that some help might be given by the University Honours Schools if they were approached. But more important was the suggested introduction of simple research facilities for lecturers. It did not seem reasonable to expect a man who had taught experimental science for years on end without opportunity to do some research, still to maintain vitality in his teaching. It seemed possible that a liaison between Training Colleges and their neighbouring University departments could lead to simple and suitable research projects, and the relatively new subject of solid state physics might lend itself admirably to this idea. Then lecturers of the right calibre would be attracted into the Training Colleges, and the quality of the existing teaching could not only be maintained, but improved.

The quality of some of the entrants to Colleges produced its own special problem, and much of the first year had to be devoted to strengthening outstanding weaknesses and helping the new student grow from a pupil at school to a student at college. Too many students, whilst competent to answer 'A' level examination questions, lacked a full understanding of the fundamentals of their subject, and an ability to deal with a problem in experimental work. Professor Garlick, in his talk on 'The Education of Physicists in the Universities', said the candidates differed markedly from the ideal student, for they were already the finished products of their school, where the effects of teacher shortage were all too apparent. There was not a good deal to choose between good 'A' level passes, but those with modest 'A' level marks had to be treated with reserve. When 'the fresher' arrived in the Honours School it was essential to put him on his toes, and to help him to make the difficult transition from being taught to learning for himself, and thinking his way through new problems. To this end a supervisor encouraged

him to put his thoughts on paper. This slowed down the all too prevalent technique of rapid scanning in their reading, and assisted in the process of divorcing the student from his established belief in the infallibility of the text-book. Moreover, the tutorial system, operating in general in the Training College and in many of the Universities, encouraged the student to think for himself and to be able to support his ideas with reasoned argument and experimental evidence.

In planning syllabuses it was agreed that they should be orientated towards modern work rather than classical physics, and a concentric view of the subject should be taken. Many of the illustrations were taken from the realm of physics not only because of its importance but because the principal speaker and a small majority of the conference were physicists. In the first year of the University course it was essential to ensure that adequate foundations had been laid, and that physics was seen as a whole. Usually great weaknesses were found, especially in the fields of dynamics and electricity. Linear motion, rotation and vibration should all be presented at the same time, for a good knowledge of vibration was a primary need of the physicist. The mechanics needed was not applied mathematics but an integrated view of dynamics.

In the field of electricity the atomic concept should be introduced as soon as possible, and it was to be hoped that schools might eventually rid themselves of the concept of the isolated pole which caused students to have such difficulties with that of the dipole. It was necessary to give students the ability to think in terms of atomic particles, whilst some appreciation of the concept of field potential, whether gravitational or electric, was very desirable. First-year study also includes mechanics, optics (especially wave motion of all types), thermodynamics and kinetic theory. The first-year course concluded with an historical account of the basis of the atomic theory which stressed the transition of thought from the classical to the modern.

During the second year an intensive course of atomic physics followed, in which the behaviour of the particles was represented in modern terms, rather than through the historical development.

The most difficult year to organise was the third. Recognising that no student could be brought to the frontiers of knowledge in three years, it was necessary to select suitable topics and study them intensively. It was also necessary to keep the number of formal lectures low, and experience had proved that a drastic cut in a heavy lecture time-table had improved the standard of work immediately. During this year fewer experiments are done, but students are given selected problems which are matched, as far as possible, to their proved ability and potential. This approach has provided a great stimulus to study, and is of far greater value diagnostically than long practical examinations, which many people felt could well be abolished. After a three-year course the supervisors gained a thorough knowledge of the student, and could give a more accurate assessment of his ability than a single practical examination would do. A sound study of nuclear physics and solid state physics seemed important, and it was felt that the unity of the subject was more apparent in these fields than anywhere else. But sooner or later the teacher comes up against the difficulties of comprehension on the part of the student, and this ultimately provides a limit to the study.

At the end of a three-year course the student should know how to learn, and where he wants to go next. The tone of the undergraduate school or the Training College department was set both by minds on the borders of the subject, and by acquiring a sense of participation in the progress of science. It is hoped that this tradition will be respected, and the weight of numbers in the 'bulge' will not be allowed to smother it.

Finally it was suggested that a degree in physics was an initial training for a professional physicist, and not necessarily the best training for teachers at all levels. The Ministry's policy of providing University places for people who can only take pass degrees proved equally distasteful to Universities and Training Colleges. The conference was confident that a good teacher training was preferable to a pass degree, and in this respect a special science degree designed for teachers was moved. Although some acclaimed the idea, others treated it with reserve, and cautioned against precipitous action.

FEEDING HABITS OF THE CHACMA BABOON

By **Prof. K. R. L. HALL** *Department of Psychology, University of Bristol*

Our evidence on the feeding habits of the Chacma baboon, *Papio ursinus*, derives from the first two stages of a general behaviour study of these animals in Southern Africa: Stage I: preliminary field work in the Cape of Good Hope Nature Reserve between April 1958 and April 1959; Stage II: intensive field, and preliminary experimental, work from July to September 1960 in the Cape and in South-West Africa. Stage II was supported by a Royal Society and Nuffield Foundation Commonwealth bursary, and by an equipment grant from the Colston Research Fund, University of Bristol.

The course of this study was planned, first, to gain systematic field data on social and individual behaviour patterns, and, secondly, to carry out naturalistic and laboratory experiments to test hypotheses arising out of the field work. The natural situation of baboons may itself vary so much from place to place, season to season, that a kind of experimental variation is imposed. Thus, flooding of land inhabited by the Rhodesian baboons at Kariba represents a man-made variation on the grand scale, bringing with it deprivation of normal food supplies, temporary crowding, and so on. Extreme climatic differences, as, for example, between the Cape Peninsula and the arid thornveld of South-West Africa, provide a natural variation affecting the feeding habits of our present species. Contrived experiments have been directed mainly at studying the learning abilities of these animals in the wild state, or with the attempt to compare the learning of this species in captivity with that of other more thoroughly studied non-human primates.[1, 2]

Fig. 1.—Baboons feeding off acacia seeds and small plants.

Field Observations

The Chacma baboon is usually credited with being more or less omnivorous, but detailed schedules of diet have been lacking. The present evidence was obtained from: (1) collection of dietary specimens after, or while, the baboons were feeding on them; (2) analysis of faeces. We made no analyses of stomach contents, for shooting or trapping the animals would have interfered with our objective of naturalistic study. Method (1) was usually adequate for floral diet, specially as we were able to make observations of one of the Cape Groups (S) at very close range. Method (2) aided us in confirming observations as well as in revealing certain types of marine and insect food which we were unlikely to identify through observation and collection.

1. Flora

In the Cape, we collected 65 specimens of plants some part of which was used as food by the baboons. In this area, the variety and all-the-year round abundance of vegetation is such that the baboons obtain a very high proportion of their total diet from it.

The behaviour patterns and perceptual discriminations used in feeding off this wide range of flora were correspondingly varied. Small plants in the loose soil were pulled up manually, and vigorously brushed against the forearm before being eaten. Large bulbs, with strong leaves, were tugged up from the ground; smaller bulbs sometimes lying as much as 18 in. below the ground were dug out, for the leaves would break with pulling. Flowers growing out from prickly stems were plucked delicately by hand or sometimes neatly bitten off. Seeds, such as those of the acacias which form in pods, were taken chiefly when the pods were dry off the trees or, more commonly, by a process of rapid sweeping aside of debris under the trees where the seeds had fallen. Pine cones were pulled off the trees, usually while still green, and torn apart with the teeth so that the kernels could be obtained.

It is reasonable to infer that the feeding discriminations and behaviour modifications appropriate to particular types of vegetation are acquired largely through social learning by the young baboons. Juveniles frequently approached close to another animal as it fed, appearing to watch intently its actions in relation to the particular plants, and sometimes beginning to feed at the same place. A young male baboon, aged about 4½ to 5 years, was released by us near a wild baboon group. It had been kept as a domestic pet for about 4 years after being obtained by its owners from near the Rhodesian border of the

Fig. 2.—Baboons foraging near coastal sleeping cliffs.

Fig. 3.—Young baboon watching another digging up a bulb.

Union. During the next 8 days, this baboon had acquired most of the feeding habits of the foster group. While some of its 'new' feeding habits were no doubt acquired simply by trial and error, it also learned apparently by closely watching the feeding of some of its new group members as these came to accept it. The part played by this type of learning requires systematic experimental study in which conditions of presentation of food and opportunities for watching and copying are carefully controlled.

2. Insects

In the thornveld of South-West Africa, our field observations in July showed that the baboons were then feeding mainly on insects obtained from the ground, and particularly by turning over slabs of rock. Such slabs were sometimes large and heavy, one which we measured being $24 \times 15 \times 5$ in.

In the Cape Peninsula, termites and their larvae were the chief source of insect food. The nests were broken open, or pulled up from the ground where they occurred at the base of dead bushes. The animals then licked up the termites, and picked off their fur and put into their mouths any that crawled on to them. This behaviour was observed sometimes at very close range—from as little as 12 ft. on occasions. Grasshoppers were also taken, as well as some species of beetle—as was determined from analyses of faeces.

3. Marine Food

Fishermen in the Cape have reported that baboons eat shell-fish obtained from the coastal rocks, and occasionally a drowned baboon is washed up on shore, presumably having been caught by a wave while engaged in this activity. We observed and filmed this behaviour for the first time in August and September 1960. It was seen in two different groups on a total of six occasions. Some of the group would typically run down to the rocks, at low tide on calm days, and forage for shell-fish in the inter-tidal pools or on the seaweed-covered rocks close to the sea. Two techniques of feeding were observed.

Black mussels were pulled off the rocks manually. A break in the shell was then made with the teeth, not, usually, with the large canines but by placing the shell between the back molars. The shell was then prised open with the fingers and the contents eaten. Limpets were usually prised off the rocks with the teeth, the animal bending right down, as in the action of drinking. We did not observe any quick-pouncing action such as might be directed at removing the limpet before it clamped itself to the rock. Discarded shell fragments of both specimens were obtained from the places where the baboons were feeding, while observation distance was sometimes close enough to make visual identification possible. We have no evidence of the baboons either cracking a mussel shell against a rock, or using a stone as a tool to aid in breaking the shell open, as is done by the Californian sea-otter, and it is clear that their teeth and jaws are strong enough for this purpose.

Other types of marine food commonly eaten by these baboons were identified from samples of faeces collected by Mr. E. Middlemiss. Two species of crab were identified from fragments. One of these is described as moving away very rapidly as soon as it is disturbed, and the baboons would have to react very quickly to catch it. A common species of amphipod, or sand-hopper,

was also identified from the faeces. We have also seen baboons with pieces of sea-weed in their mouths, but whether they were eating this or whether it was attached to a shell-fish, we had no means of discovering.

When engaged in getting shell-fish, the baboons would sometimes sit very close to the sea, even with their backs to it, and would sometimes have to rush away to avoid a wave.

4. Dietary Variations

A curious variation in diet was observed on a few occasions in S group. Some of the animals were seen to eat chunks of damp clay in a disused quarry and from another area near to the Cape of Good Hope. The clay was dug up and actually eaten, not merely licked, the animals' lips appearing white in consequence. Samples of the clay were obtained, but they have not yet been analysed.

A more important variation concerns the baboons' alleged partiality for birds' eggs and young, and the young of buck or sheep. A young baboon of S group was given a hen's egg, but merely played with it, pressed it and rolled it, then bit it open but let the contents slide down the rockside, and made no attempt to lick or eat it. An adult male baboon of the same group licked up the contents of a raw hen's egg which was thrown to it from a visitor's car. Nesting crowned plovers showed high-intensity alarm and diving-threat behaviour when a baboon group was foraging for bulbs over the nesting area, but the birds might have behaved in the same way if the intruders had been ungulates, as we have observed when cattle have approached a nest. We have thus no satisfactory evidence as to this type of feeding in baboons, and we can only refer to the reports of game wardens that baboons in some parts of Africa will eat both the eggs and the squabs of ground-nesting birds such as partridges, francolins and guinea-fowl.

Baboons are sometimes described as the only living non-human primates to acquire habits of killing and eating the young of other mammals. Zuckerman[3] did not give credence to the many accounts by South African farmers of their losses of lambs through baboon predation. He considered that the frequently observed peaceful coexistence of baboon groups and ungulate herds belied these accounts.

Since then, there have been incidental reports, and some film records, of the carnivorous habits of baboons in various parts of Africa. Oakley[4] has summarised the evidence he obtained from the accounts of farmers and game wardens in South Africa, with particular reference to the statements of Captain Potter, formerly Chief Game Warden of the Hluhluwe Game Reserve in Natal. Farmers in South-West Africa reported to me that baboons regularly killed and ate the lambs of the Karakul sheep. The Southern Rhodesian Rescue Team at Kariba told me that they had observed baboons on one of the islands eating from the carcase of a small antelope. A great deal more systematic observational and film evidence is needed on this interesting variant.

In South-West Africa, it was also reported that baboons will eat two of the common species of back-fanged snake. If this report could be verified, it would be a remarkable instance of learning, through necessity, to inhibit an instinctive avoidance reaction. We have shown with models,

Fig. 4.—Rock overturned by baboon in search of insects.

and seen with a similar species of back-fanged snake in the Cape, that the baboons' immediate reaction here is to leap clear of the snake.

5. Conflict Behaviour Patterns

Concepts, such as those of displacement activity and redirection of drive, arising from ethological studies of lower vertebrates, may also be found to apply to the behaviour of non-human primates in disturbing situations, and may affect the feeding behaviour patterns. Thus, Carpenter[5] describes 'sham feeding' in the Howler monkeys in two types of situation where the animal's motives are conflicting and the 'casual' leaf-plucking that takes place is '. . . a kind of camouflage of the true quality of the behaviour'. This sham-feeding seems to differ from such behaviour patterns as are described in birds in that it is associated with disguise of real intention. We have not yet observed anything of this order in baboons, and the only instances where 'casual' feeding reactions have been seen resemble curtailments of the full behaviour because of some distraction. In other words, the reactions were not irrelevant to the motivation presumably dominant at the time.

Another kind of behaviour in baboons which may be an extension of a feeding reaction is their alleged rolling or throwing, of rocks over cliffs in the direction of human intruders below them. We have no observations of such 'intentional' behaviour, although we have sometimes seen young baboons dislodge quite large rocks when scrambling up slopes in alarm or even when simply searching for food. We have, further, seen baboons, disturbed by our close presence, pulling back violently on branches or large rocks. Such reactions are to be seen in their normal feeding behaviour, and it seems simplest to treat them, provisionally, as somewhat exaggerated expressions of the same motivation rather than as true substitute activities. It is clearly possible that such reactions could be generalised to occur to a 'new' objective, such as dispersal of a predator.

6. Day-ranges and Feeding Areas

Our observations show that baboon groups in the Cape Reserve range, normally, for their food within a definable area. Thus, Group S, in August and September 1960, averaged 2·9 miles for 15 complete day-ranges, with a minimum distance of 2·1 and a maximum of 4·1 miles. The day-range began from the overnight sleeping place on the steep cliffs at about 30 to 60 minutes after sunrise and ended with the return either to the same sleeping place or to another one within their area at about sunset or up to 30 minutes later. On most days, at least three-quarters of the time of most of the group was spent in searching for food and feeding, i.e. some 9 hours at this time of year. In heavy rain, the group would interrupt its feeding to take shelter, and on warm sunny days they would sometimes rest and groom in the early afternoon. This same group, in 1958–9, averaged for 8 day-ranges 2·3 miles (minimum 1 mile, maximum 4·5 miles). Distances covered thus remained about the same as between these two sets of observations, even though, in the intervening 15 months or so, the number of animals in the group had been reduced by shooting and trapping from forty to twenty-six. The home area had not altered over this period, the ranges all falling within a triangular area, bounded on two sides by the coast, of $5{\cdot}2 \times 4{\cdot}6 \times 2{\cdot}4$ miles.

Fig. 5.—Probable mixed-motive expression of young female expecting to be offered food.

C group ranged over an area to north of S, but overlapping with it by about ¼ mile at some points on the 'boundary'. The average of 10 day-ranges for C, in 1958–9, was 3·2 miles (minimum 1·5 miles, maximum 5 miles). C numbered fifty-three

to fifty-four animals over the period of observation. In South-West Africa, the day-range of one large group, numbering sixty-five animals, was 12 miles.

I have deliberately avoided using the term 'territory' to describe the definable area within which a baboon group may range because it usually connotes inter-group exclusiveness and hostility. So far, we have observed encounters between two groups of baboons on six occasions, on none of which was any hostility shown. This conforms with Emlen's[6] preliminary report on such encounters between gorilla families.

Fig. 6.—Threat between females, probably over food.

7. Dominance in Relation to Feeding

Priority of access to food is one of the dominance criteria used in studies of the social organisation of animals. A sample of nearly 200 hours' intensive observation of S group in the Cape demonstrated, in various ways, the dominance behaviour of the largest male. In feeding this was shown by his chasing away of other animals when a desirable food-object was located by him, by the other animals' giving way to him on his approach to a bush where they were feeding, and by their avoidance of approaching close to a patch on which he was already feeding. Exceptions to this were to be seen chiefly in his tolerance of one or other of the females with whom he was mating. Quarrels over food were fairly frequent, as amongst the females and the young, but were noisy rather than injurious.

8. Direction of Day-ranges

It was often difficult to determine, even from the close range observations of S group, which animals in a group initiated movement from the sleeping places or a change of direction of the group. Sometimes it was evident that the largest male led the movement, not necessarily in the spatial sense of being ahead of all the rest, but by deliberately going in a particular direction. On other occasions, however, one, and sometimes two, of the large anoestrous females appeared to initiate, and to maintain, the course the group took. This occurred most noticeably when the largest

Fig. 7.—Largest male of S group.

male was, during the day, actively engaged in mating with an oestrous female. This group always maintained its coherence, even though sometimes scattering over about ¼ mile of country while feeding. Cohesion was maintained chiefly visually, while communication by low grunting was frequent when the group was feeding in thick bush.

EXPERIMENTAL OBSERVATIONS

Many of the details of certain types of feeding behaviour may, except when an unusually tolerant group is involved, be difficult to discern under normal field conditions. Experimental studies of captured animals, even of a preliminary nature, may therefore add valuable information, while the natural experiments provided by such human paraphernalia as cars may also give us clues about learning dexterities and conditionability.

1. Instrumental Acts

S group has, over many years, become conditioned to receive food occasionally from the cars of visitors to the lighthouse area of Cape Point. Individual animals have acquired considerable skill in opening car doors and boots. We have observed such performances on many occasions both on our own vehicle and on others. One instance was where an adult male baboon, after opening the car door, sat in the front seat, opened two compartments on the dashboard and took from one a glass jar containing barley-sugar. It was then chased from the car carrying the jar in one hand. It sat on a tree stump, unscrewed the lid and inserted its hand. On being chased again, it ran off with the jar over its hand like a glove.

These baboons, when coming to occupied cars, typically peer through the windscreen, and, if prevented from entering the car and not receiving food from it, may sometimes generalise their manipulations to pulling off windscreen-wipers, pulling out traffic indicators, and bending wireless aerials.

Preliminary experimental studies were carried out on this type of performance and on elementary tool-using, all of which we can class as instrumental acts, with two young male baboons that had been in captivity two to three years. Animal C, tested from a large cage in the laboratory, learned very rapidly to open problem-boxes in which it had seen food placed and where the manipulations consisted of lever-raising, removal of a padlock before lever-raising, etc. It also learned easily to pull in food attached to the end of crossed strings, and to use a wooden rake the correct way round to bring in a banana. Animal T was tested with the Köhler-type[7] situations, a broom or a walking-stick being placed at various distances and angles from itself and the reward placed on the ground; and boxes being placed so that they could be used as aids in reaching a reward suspended out of reach. It succeeded on the horizontal-plane tasks without difficulty, but, in the short time available on the vertical plane task, succeeded only in using a single rectangular box which it turned long-side up in order to reach the reward. These observations, using conventional props, can merely indicate that the instrumental skills of these animals are of quite a high order, and may reasonably be compared with those of chimpanzees and rhesus monkeys. They can indicate no more than this because the details of their pre-experimental experience were not fully known to us. Much

trial-and-error was evident in their performances, as well as generalisation of previously-successful responses to new tasks. In nature, young baboons are sometimes to be seen carrying tree branches, apparently as a form of play and without any reference to feeding. They have never been seen to use such objects as instruments for obtaining food.

Fig. 8.—Young male after pulling at windscreen-wiper.

2. Food Discriminations

In South-West Africa, we experimented with a young male baboon captured from a group 24 hours before presenting it with various food-objects during the following two days. Offered live scorpions, it immediately grabbed them in its hands and bit them from the head end first before swallowing. It made no attempt to withdraw the sting, and it suffered no harmful consequences. Because of its wildness, however, we were unable to test it in a 'natural' situation, as by placing the scorpion under a rock, and the live insect was handed up to it as it sat on top of a pole. This animal, from the same position, also grabbed and ate a reputedly poisonous species of millipede, as well as locusts and spiders, and a legless lizard, 9 in. in length and very much alive and wriggling, which it stuffed into its mouth like spaghetti and swallowed. It rejected two species of lizard and a small rat.

In contrast, the male baboon T, of about the same age, who had been in captivity 3 years, avoided scorpions, millipedes and legless lizards when it discovered these under stones or in paper-bags or boxes where they had been placed.

No conclusions are possible from these few observations, but they suggest interesting possibilities for extended experimental research

Fig. 9.—Recently captured baboon about to take and eat live scorpion.

particularly on recently captured animals whose feeding-experience after capture can be fully controlled. The ingestion of poisonous insects is an interesting phenomenon, and one would wish to study very fully, on many more animals, the behaviour associated with this.

Further progress in the study of the feeding habits of baboons is likely to come chiefly from naturalistic experiments of discrimination learning and retention, of observational learning (imitation), and of the instrumental type already described. Field observations are likely to be of greatest value in the abnormal situations provided by isolation of groups at Kariba where modifications of individual and group feeding patterns could be systematically studied.

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PSYCHOLOGICAL ASPECTS OF FOOD ACCEPTANCE, WITH SPECIAL REFERENCE TO FEEDING THE UNDERPRIVILEGED

By Dr. ROLAND HARPER *Department of Psychology, The University, Leeds, 2*

Introduction

It is my intention to outline here some of the psychological problems of food acceptance, with special reference to feeding the under-privileged. My personal interest in problems relating to foods dates back to 1946 when, for several years, I was engaged in the study of the skills of cheesemakers and graders and of their products.* At that particular time flavour was considered to be of minor importance and since cheese was severely rationed the question of choice hardly arose at all. My regular contact with the Dairy Industry ended in 1950, but I have maintained a continuous and ever-widening interest in the psychological problems of food assessment and food acceptance.† The special problems associated with feeding the underprivileged are a further practical extension of this theme.

Much attention has been devoted to the scientific problems of food production and nutrition, but the psychological bases of food acceptance receive less attention than they merit for the practical value of other approaches to nutritional problems is set by *what people are actually prepared to eat*. This fact is well illustrated by the title of a paper by Dove (1943) in which he referred to 'measuring foods in terms of their psychological and nutritional values combined'.

* This work was carried out at the National Institute for Research in Dairying, Reading.

† 'Psychological aspects of food assessment and food acceptance' formed the theme of a symposium at the Annual Meeting of the British Psychological Society held in Hull, April 1960.

Food Acceptance as a Psychological Theme

A brief definition of contemporary psychology and some indication of why this has any bearing upon the problems of food acceptance are required here. Psychology might be defined as the systematic study of human behaviour and experience by observation and experiment. It is essentially an empirical discipline, in so far as speculations which do not lead to testable conclusions are not encouraged. In the past, some non-psychologists have used the term 'psychological' to refer to what is left over after all possible systematisation of human food responses has been achieved in physico-chemical and physiological terms. This is a fallacious point of view for scientific psychology is just as much concerned with achieving the maximum permissible degree of systematisation of information about the more obvious forms of human behaviour and experience. The challenge of psychology is *that of how to think systematically amongst variability of a highly complex origin*. This phrase aptly describes the problems involved in a systematic approach to food acceptance. Peryam and others (1960) have recently provided a valuable illustration of the scope for systematisation by showing that, in large groups, a substantial degree of prediction of preferences and actual choice of foods can be achieved by the simple procedure of noting the extent to which various food items are liked or disliked.*

* In statistical terms these authors have indicated that between 35 and 60 per cent of the observed variation in food acceptance can be predicted from such data.

Until recently psychologists have tended to neglect human food responses as a subject for investigation, yet there is no theme which involves more intimately the whole range of human behaviour and experience. Other human needs have long been the subject for psychological studies and theorising, but it is only during the past fifteen or twenty years that the comprehensive study of food assessment and human food acceptance problems has been undertaken with increasing co-operation from psychologists. (The rise and development of this work has been summarised elsewhere—see Harper, in press.) Problems of food acceptance can be approached from a number of different points of view involving different levels and orders of complexity. The following list indicates a few of the relevant approaches:

1. The study of human sensitivities including taste, smell and sight and their relation to food habits and preferences.
2. Establishing the main dimensions, or systematic variables affecting human food responses. These include a descriptive approach through commonly accepted language, the expert assessment of foods, physical, chemical and biochemical analyses, and the collection of systematic information about human likes and dislikes.*
3. The direct survey of food habits as a source of factual information which may be used for a variety of purposes, including the delineation of individual, regional and national differences and of changes in these.
4. The study of factors underlying spontaneous changes.
5. The study of factors associated with deliberately inducing changes in food habits in the light of various pressures including the need for improvements in nutritional practice.
6. The study of the interdependence of the various types of information noted above.

* Certain of these 'dimensions' were outlined in a contribution to the Symposium on 'Taste, appetite and the selection of food', British Association, Sheffield, 1956 (see Harper, 1957). They were also effectively discussed by Pilgrim (1957).

Some Practical Approaches

On this occasion attention is deliberately restricted to some of the more practical issues relating to food acceptance. One of the principal problems in such a complex situation is that of posing the right questions; that is, questions to which meaningful and useful answers can be obtained. To some extent a natural history approach assists here. Useful insight can be drawn from various sources. For example, experience obtained in improving the feeding habits of the poor in this country during the first few decades of the present century is directly relevant. Many sources could be quoted but the following quotation from B. S. Rowntree (1901) describes a situation which might well suggest the attitude of the under-privileged to attempts to improve their feeding habits. Rowntree wrote:

> At present the poor do not possess knowledge which would enable them to select a diet which is at once as nutritious and as economical as that which is adopted here as the standard. Moreover the adoption of such a diet would require considerable changes in established customs, and many prejudices would have to be uprooted.†

Another useful source of information comes from deliberate efforts made during the Second World War to change food habits in the light of the immediate needs of that time. A systematic approach to the various problems involved appears to have been developed more in the United States than in the United Kingdom—at least published information is more readily accessible concerning American experience.

At an early stage of this work Lewin, a well-known psychologist, stressed the necessity of collecting objective information about conditions before and after attempts to make changes. He drew attention to the (psychological) fact that in the absence of such objective evidence the evaluation of progress becomes largely a matter of personal temperament. These studies led Lewin to emphasise the value of small group discussion techniques as an effective method of stimulating

† This quotation was taken from a paper by Drinkwater entitled 'Seebohm Rowntree's contributions to the study of poverty', given to the British Association Meeting in York, September 1959.

interest and active participation in the use of unfamiliar foods (see Lewin, 1947, for a report of this work, which was carried out several years earlier).

Amongst the many relevant and interesting points made in the two reports of the (American) Committee on Food Habits (1943, 1945) was the importance of finding out exactly what existing food habits are, rather than blindly trying to change them without adequate background information. Margaret Mead, the cultural anthropologist, was the executive secretary of this Committee and in a more recent review of 'Cultural Patterns and Technical Change' she has referred to a number of striking successes and some failures in attempts to change food habits in different parts of the world (see Mead, 1953). This American experience appears to have directly affected the activities of the Food and Agricultural Organisation and of the World Health Organisation in the various nutritional programmes of the post-war era. The first stages of this work were largely concerned with feeding refugee and other groups suffering from immediate post-war food shortages. Many informative examples of unexpected responses to foods made available can be obtained from the reports of these and other organisations.* Gradually systematic programmes of work have spread to the under-privileged in different parts of the world. Ethnologists and cultural anthropoligists have again played a dominant role in collecting the relevant data. This has been most desirable for the role of 'culture patterns' is of vital significance in the correct interpretation of needs, responses and outcomes. Clearly, the problems encountered in the collection of information about food habits and in inducing changes in them are very different amongst the under-privileged as compared with the problems facing investigators concerned with 'action research' in Western communities with well-developed means of mass communication, market research and advertising.†

It is useful to contrast these Western studies with recent material on the problem of protein malnutrition. Details vary from one investigation to another, but the following general picture has emerged. Sometimes, bad feeding habits are based upon ignorance rather than poverty and a knowledge of local customs is essential. Not only is it necessary to know what the feeding habits are in general terms but one must also know who actually gets the food. For example, amongst a group of South African Zulus, Cassell (1955) noted that the married women were excluded by custom and by kinship ties from milk-drinking. This particular problem was overcome by using powdered milk which was sometimes referred to as 'meal'. This is only one of a large number of possible examples illustrating the complete antithesis between the type of thinking involved in the choice and acceptance of foods with its irrational and unconscious undertones and the traditional conception of scientific thinking. However, the advertising methods commonly adopted in this country to stimulate the sales of new foods and to maintain the sales of established ones largely conforms with this notable emphasis upon irrelevant features, so evident in primitive examples of food responses.

On the Acceptability of Novel Foods

It is convenient here to link the efforts to alleviate protein malnutrition with one example of the novel types of food and nutritional supplements made available through modern science and technology. Pirie and his colleagues from Rothamsted have prepared several different forms of edible leaf protein from materials which, in their original form, could not be used as human food. Relevant aspects of this work have been summarised by Pirie (1958) and by Morrison and Pirie (1960). There is an overall world shortage of protein and the possibility of providing an acceptable supple-

* A private communication refers to the rejection by one refugee group of a free consignment of Swiss cheese. This was for mixed reasons, including the fact that the cheese had holes in it! This condition, which is a characteristic of Gruyère cheese, was associated in the minds of the group with inferior quality. It must also be added, that the local preference was for their own goat's-milk cheese and anything new or foreign did not conform with the 'taste' of this refugee group.

† Typical information of the second type has recently been brought together in this country by Crawford (1958) in a market research study of 'The Foods We Eat', and Peryam and others (1960) have summarised information about the food preferences of American servicemen, based on a number of extensive surveys over the last ten years.

ment from plant leaves is of great potential importance, especially in those regions where protein malnutrition is actually present. However, most novel foods present serious acceptance problems and leaf protein is no exception. It has a very deep green colour, an unusual flavour and, in certain forms, a dry and cloying texture. (To me the flavour of freeze-dried leaf protein is intermediate between the taste of spinach and the odour of hay.) Various suggestions have been made for increasing the acceptability of this product, such as blending small quantities with highly flavoured dishes of an exotic type. Undoubtedly, leaf protein is not to everybody's taste although there are reasons to believe that it may become more acceptable through sheer habituation. Pirie has suggested that acceptance is also improved if the person eating the leaf protein is able to produce his own mixture on the plate. He also reports in a personal communication that in certain regions, including parts of Ghana, successful acceptance has been achieved.

A number of additional comments of relevance might be made here. There is scattered evidence that the taste of many common vegetables presents serious acceptance problems. For example, it has been found in several American investigations and some in the United Kingdom that a high proportion of persons strongly dislike certain vegetables and that these include several of the strongly flavoured leaf vegetables. Undoubtedly there are very marked individual differences here and there is a possibility of some changes with age. Since the greater part of the information on this particular problem is of Western origin it would be interesting to know whether these aversions are of social origin or whether they are more widespread and more deeply rooted.

Summing up

By way of conclusion some of the main points will be repeated. Personal interest in this particular problem is an extension of a line of investigation relating to cheese, since which I have continued to examine the relevance of contemporary psychology to human food responses. Various lines of work open up under this heading, but on this occasion emphasis has been placed upon the socio-psychological problems, because these are perhaps of most immediate importance, especially where the application of nutritional knowledge to other countries with very different 'culture patterns' from our own is involved. I have argued that useful guidance about the way people react can be drawn from reports of the problem of feeding the poor in the United Kingdom, earlier this century. Studies directed at deliberately changing war-time food habits illuminate the problem before us and emphasise the overriding necessity of factual information about food habits and who gets the food. One practical illustration of the acceptance problems posed by novel foods has been provided by the development of leaf protein as a potential source of human food of special significance owing to the world shortage of protein and the considerable amount of protein malnutrition known to exist.

If, in this paper, I have neglected various approaches to food acceptance problems which are more strictly in the analytical tradition of science then I have done so deliberately. My general attitude may be summed up in the concluding words of P. T. Young (an American psychologist who has been working in this field for over thirty years) in a contribution to a recent symposium on 'Nutrition and Behaviour'. Young (1957) ended with these words:

> . . . the science and art of feeding men and animals must rest upon psychologic(al) principles as solidly as it rests upon the principles, of physiology, chemistry and the science of nutrition.

Too little attention is devoted to clarifying and applying these psychological principles, a selection of which have been considered in this paper.

Finally, may I place on record my special thanks to the following individuals who have drawn my attention to relevant information which would otherwise have been missed: Dr. J. M. Bengoa and Dr. R. C. Burgess (Nutrition Unit, World Health Organisation, Geneva), Prof. G. R. Hargreaves (Department of Psychiatry, University of Leeds), Miss E. P. Jordan (British Red Cross Society), D. R. Peryam and Food Acceptance Branch staff. (Quartermaster Food and Container Institute for the Armed Forces, U.S. Army, Chicago), and N. W. Pirie, F.R.S., and associates (Leaf Protein Unit, Biochemistry Department, Rothamsted Experimental Station).

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THE TEACHING OF FRENCH TO MODERN SCHOOL PUPILS: AN EXPERIMENT

By JOAN TINTON *Doncaster Training College*

The decision to carry out my experiment was prompted in the first place by a demand on the part of the children in the Modern School where I was teaching. They wanted to learn a language. It was not usual then to offer such children a language, and in fact even now only a minority of children in English state schools are given that opportunity, although children in nearly every other European country learn at least one foreign language as a matter of course. Paradoxically, although we expect the people of so-called 'backward' countries to address us in English, we seem to assume that for most of our own children language-learning is too 'difficult'.

I hoped to take a step towards the answers to questions such as these: To what extent should foreign languages be taught in our schools? To what extent can foreign languages be learnt, and to what extent do they need to be?

How many of the population are capable of learning a language? The answer to this question has long depended upon the generally held assumption that language learning was 'difficult', and therefore only to be attempted by the most intelligent, or by those who had a very strong vocational incentive.

This belief in 'difficulty' stems largely from the methods of teaching used in the past. Before the days of printing, boys learnt Latin, the international language of Europe, in the same way as they had learnt their mother tongue—by daily conversational use. Then came Gutenberg, printing, and eventually the text-book. The early text-book writers set out to 'systematise' the material, in order to make of their Latin a neat, logical and scholarly presentation. They did not apparently pay much attention to 'systematising' the way in which a child's mind might be brought to build within itself, and make use of, a similar pattern of subject-matter. As the demand for text-books grew, their writers succumbed to the next temptation—the elaboration of their systems and the addition of endless, often useless detail—if only, one suspects, to exhibit their own erudition and make more of a 'mystery' of their trade. Through the following centuries, in spite of protests from enlightened educationists, the grammar-by-rule, vocabulary-by-list type of Latin or Greek text-book continued to be used, right down to the middle of the nineteenth century, when it became fashionable to learn a 'modern' language. Then the same approach was adopted with modern languages. They were in fact taught as if they were dead languages, and it is not surprising if the young pupils in the mushrooming schools of the last century found that French and German were quite as difficult as the 'Classics', and that when, with the aid of the birch, they had mastered them, they were almost as useless for any practical purpose.

The methods of reformers, who since the 1880's have been trying to encourage a more direct approach based on speech, are still not universally accepted. Many text-books still in use are badly arranged, and cluttered with irrelevant or useless material.

Many teachers seem to believe that the grammar-book method is a safer and quicker way to examination success. If we were simply aiming at passing examinations, I suppose this would not matter very much, but it does not work. Some supposedly bright children still contrive to gain only 10 per cent of marks at the G.C.E. 'O' level, and one examiner has described the average achievement of those who do pass this examination as 'paltry beyond description'. If there is such difficulty in the subject that the 'lower streams' of grammar

schools cannot learn it successfully, what hope is there for the rest of the population?

In this century, ever wider attempts have been made to bring languages first into the elementary schools, and more recently into Secondary Modern Schools; and the Ministry of Education, in Pamphlet No. 29 (published in 1956, during the course of my experiment) stated that the teaching of a foreign language in Secondary Modern Schools could no longer be regarded as experimental. In a city such as Sheffield the number of Modern School classes learning a language increased during the five years from 1953 to 1958, from ten to seventy-five. However, it was still assumed that only the brighter children could succeed. The question as to whether *all* children, if they and their parents wished, could make any worth-while progress, was still unanswered.

The Aim in Teaching a Language

If we accept that the majority of our children will have no vocational use for a foreign language, what other claims are there which would make its inclusion in the curriculum worth while? And if we accept that there is a good argument from the social, international and cultural points of view, is it also true that the majority of pupils would be able to achieve a sufficient knowledge?

First, there is the gain to the nation in international understanding and sympathy. In this shrinking world, far more people have contact with foreigners than ever before, and not only does the student of a language obviously learn something about a foreign country, he learns by comparison a great deal about his own. 'What do they know of England, who only England know?'

There are six ways in which an individual may benefit, quite apart from the narrow vocational one, and quite apart from examination passing:

1. by gaining a wider perspective of the world in general,
2. by gaining an increased understanding of the nature of language itself,
3. through the possibility of travel and correspondence,
4. by acquiring a basis for later language learning if it proves necessary,
5. by opening a door to foreign culture, and
6. as an 'accomplishment' for leisure.

To what extent could these gains become a practical possibility for most children? If they were to be achieved, the children would have to be given a sufficient liking for a language and a sufficient competence in it to lead to at least some of these benefits. It seemed that to justify the time, energy and expense involved, the children would have to learn, in five years, to

(*a*) understand the spoken language,
(*b*) pronounce the language in an understandable manner,
(*c*) converse intelligently upon subjects within the range of their own experience,
(*d*) understand the meaning of the printed language at a simple level,
(*e*) write fairly freely, if not accurately,
(*f*) have a much wider knowledge of the country and people concerned than they would normally acquire from their History and Geography lessons, and
(*g*) wish to make a further use of the language.

Could this be done in five years? Could it be shown that such aims were reasonable for the Modern School? Any experiment which tried to show that they were would have to be carried out in normal Secondary Modern conditions. I decided that I would have to accept things exactly as they were: the assumed limited mental ability, the limited lesson time (less than the minimum recommended by the Ministry), and—the only thing that is not limited, size of class—classes nearly twice as large as the largest recommended in any treatise on language teaching that I have found. The case would have to stand or fall regardless of these disadvantages, which will probably always be with us.

I decided that I would base my work on Goethe's dictum that 'all we can remember of our studies in the end is only what we have been able to find practical use for'. The Modern School pupil must leave school with the language *in his head*: not for him the painstaking mosaics created by the grammar-taught child with the aid of dictionary, grammar and verb-list. By the end of the present four-year Modern course I hoped that the children would have the ability

in Conversation—to answer questions on everyday matters,

in Composition—to write the equivalent of a simple letter,
in Reading—to read well enough to be able to continue reading after school,
in Vocabulary—to use 1000 words 'actively' and a further 2000 'passively',
in General Knowledge—to retain some knowledge of the Geography, History, culture and customs of the country.

The Method and Content

Obviously the methods would have to be the most efficient I could find. There was no time to waste, and no time to risk losing the children's interest. I was trying to *teach* children, not merely to instruct them. When our object is to make, through the teaching of any subject, a qualitative change in both the 'mind' of the child and in his whole attitude to his future life, we cannot work on a 'jug and mug' principle. I am speaking of 'mind' as an activity of the brain—a process as yet, even to Science, mysterious and partly incomprehensible. It is of no use whatever to sit down beforehand and make lists of what must be done. One can only indicate broad probabilities, and then let the study grow as the children's knowledge grows. To say, 'We will do Lesson 4 by Christmas' is to make a statement that has only a fortuitous connection with teaching and learning.

To say, however, that the learner does his own learning is not to say that he can be left to his own resources. There *is* a task for the teacher. It is a heavy one, and it is twofold: to ensure that the learner is motivated to learn, and to ensure that the material is presented in such a way that his application bears fruit in the form of mental growth or change.

Once the child is motivated to learn, preferably by a desire arising out of the subject itself, he must do his learning in an organised way. He can, it is true, learn a great deal simply by copying teacher, by listening to teacher's explanations, and by learning by heart, but nothing that is 'learnt' in this way is actively usable by the child unless he sees and understands the connections between such things and the true, active, knowledge that is already in his mind. If he does not make these connections, the material will remain passive. That is, he may be able to recall it, given the proper cues, but he cannot apply it spontaneously or meaningfully in its full context. He is rather like the budgerigar who has been taught to speak and replies indiscriminately to a question like 'What is your name?' with 'Would you like a cup of tea?' He has learned to talk, yes, but not to talk sense.

The teacher must present problems in such a simple way that the relations involved are not beyond the learner's powers of mental organisation. If this is done the learner, whatever his 'intelligence', will be able to exhibit direct insight and will have 'learned intelligently', or as the Gestalt psychologists would say, he can make a good Gestalt. It is plain that, when it happens that some of the children in a large class have not succeeded in making a good Gestalt, for the teacher to go on to a subsequent, dependent step can only cause bewilderment, confusion and eventual apathy. The teacher who is using an oral method with a reasonably sized class should be able to detect such misunderstandings before they become hardened into habits or achieve the immutability of ink.

Much of this applies to any subject. This is not the place to go into detail. Suffice it to say that in planning the work I tried to make as much use as possible of the results of recent studies in motivation, in insightful learning, in work with slow learners, in 'activity' methods, in the effects of group work, in the modified use of the 'direct' method, in 'inductive' methods, and so on. I do not claim to have invented a novel method. Well-tried techniques were to be used as and when I felt they would arouse the children's interest and provoke learning activity. The phrase 'active oral' is perhaps the best way to describe it.

New material was to be presented orally, in the form of situations or scenes. Correct pronunciation, and as far as possible intonation, were to be insisted upon. Learning orally, from situations, the pupil hears sentences first, and though they may be very short (perhaps only one word of command), they relate to action. As Piaget has reminded us, we talk in sentences, not words. There are primitive tribes who do not realise that the language they speak is analysable into separate words. Language is sentence, plus correct pronunciation, plus correct intonation, and when an active-oral method is used these three are always presented together, as they belong. Likewise, for the young child and the primitive, words and the

deeds they represent are one. If the word and the deed are performed at the same time in a language lesson, they tend to be remembered together.

In order that no-one might be left behind, repetition had to be copious, but this did not mean the mechanical copying of a phrase in one set way in order to teach it. To do this would probably have meant that only the brighter children, who understood at the first flash, were assimilating anything. (Repetition of that kind is only of use when understanding has first taken place.) The kind of repetition referred to here is repetition of presentation in as many different ways as possible, so that all the children are given an opportunity of insightful learning.

The syllabus had to be elastic, and it was formed, not on a framework of grammar with 'interest' applied afterwards, but on a framework of situations or topics, with the grammar applied afterwards. The language would be understood first, and the grammar would follow. Actions and sentences would be understood, and the vocabulary would follow.

Because so much more care would have to be taken in both presentation of material and consolidation at each stage, the less intelligent child would quite obviously have to go more slowly, and this would result in his doing *less* grammar and written work, not more, as is sometimes thought to be the case.

Let it not be assumed that this points to an 'easy way' for the average child. On the contrary, he has to work quite as hard as his brighter friend. The apparent absence of grammar, and presence of 'activity' may mean that the children are enjoying themselves. It does not follow that they are not working. They are 'thinking for themselves', as the careless cliché has it.

No ready-made course, or text-book, or grammar, was to be used, but this did not mean that the children would not need a reference book of some kind. So each child was to make her own vocabulary and grammar reference book, only entering material which had been thoroughly understood and learnt first. It would be entered on numbered pages, so that the book could be carried up the school and used for reference. There would be valuable training in accuracy here.

As a guide to the order in which material should be introduced I used the French Government publication *Le Français Élémentaire*. This is a list of the 1138 words most frequently used in day-to-day conversation in France.

Translation was not to be used as a teaching method. Involuntary mental translation is inevitable in the early stages of learning any vocabulary or speech-pattern, but constantly and deliberately to refer children back to the mother tongue is bound to result in slower learning and faulty grammar.

The Experiment

I felt that those were the methods most likely to succeed with Secondary Modern School children, and I accordingly undertook the teaching of French to six classes, 235 children in all, by these methods. As each class reached the end of its second year the children were to be tested, and the results were to be compared with those of Grammar School children doing the same tests at the same stage.

My six classes were of 31, 40, 44, 40, 44 and 36 children respectively. They were four 'A' streams, a 'B' stream, and a 'D' or lowest stream. Their I.Q.s ranged from below 70 to 124. They were taught according to the methods already described, and I used all the following activities:

> question and answer, chorus work, games, dramatic work, Gouin series (chains of actions), reading aloud and silently, singing, some rote-learning, all kinds of written work (provided it was in French), phonetic practice in sounds and speech patterns, gramophone, tape-recorder, radio, illustrative materials of all kinds, magazines, comics, films, film-strips, visits to Paris, correspondence, and an out-of-school club.

The 'B' stream proved quite capable of covering the same ground as the 'A' streams did, with the difference that their written work was not so good.

Perhaps it would be worth while to spend a little time on the response of the 'D' stream. At the outset their enthusiasm was a joy to behold: it altered their whole attitude to school life at the transfer. Many of them could not be said to read or write properly in English yet, and I knew that it was theoretically bad to start them on another language while they were still at this stage of their

slow development. But it was all or none, so we began. Some of their I.Q.s had proved unmeasurable by group tests at 11-plus, and had been recorded as 'below 70'. The next lowest group were 70, 74, and three 75's, and the bulk of the rest were in the lower 80's. (These are the children who are expected to find any learning very difficult indeed.) Newcomers to the class insisted on joining in and catching up. They would willingly copy out the grammar reference book in their spare time, even to a girl who came to the school in the middle of the second year. I told her that she could not join in the French lessons, that it was too late; but she came to me on the following Monday morning with an exercise book into which she had spent the weekend copying out accurately and in readable writing no less than twenty-six pages of the reference book. I could hardly refuse her after that. She continued to work hard in her spare time, trying to catch up, and she was included among the children who were tested at the end of the year, having caught up very well indeed.

The hardest thing about teaching such a class was their irregular attendance. The difficulty of teaching by oral methods, when five or six children, and always different children, are absent for practically every lesson, can be imagined.

Throughout the first year, however, they made a very brave effort, and as far as oral work was concerned they were actually working lesson for lesson with the 'A' stream. In the second year, though, I began to worry. I began to feel that I was being, if not cruel, at least not kind. They were willing to make such tremendous efforts, but they just could not keep up, and the course for them had to be considerably modified. They did however very pluckily take the battery of tests at the end of the second year, and some of the results they achieved were quite surprising.

There was no doubt that these children enjoyed the work. At the end of each term after the second year (when they had completed the experimental period and worked the tests) they were allowed to vote as to whether they wished to continue. They went on through the third and fourth years, showing great satisfaction, and being always eager to join in any oral activity. Had I been able to include a 'C' stream in the experiment it is only reasonable to suppose that they would have done even better.

The Test Results

The tests set were in vocabulary, grammar, dictation, composition, translation, reading for information, comprehension, reading aloud and conversation. All the tests were standardised and validated according to accepted statistical procedures.

The standard of comparison was made by giving the same tests to four other classes, three in Grammar Schools and one in an Intermediate School. The four classes chosen were being exceptionally well taught, by methods similar to mine. There were four major differences in the conditions here. Quite apart from 'intangibles' such as home background, incentives, etc., there were the questions of size of class, time allowed for French lessons, and the measured Intelligence and English Attainment Quotients as scored at 11-plus.

The Modern classes averaged 39 children: the Grammar classes 32. The Modern classes averaged 140 minutes per week, the Grammar classes 190 (nearly an hour a week more). The Modern 'A' and 'B' streams together had an average I.Q. of 109, the Grammar classes together, 120. The English results at 11-plus had shown an average for the Modern 'A' and 'B' classes of 112, whereas the Grammar Schools averaged 123.

It was to be expected that if there was a special difficulty in language teaching the results in the French tests would show a marked cleavage. In the event there was a considerable overlap.

It is true that the two best Grammar School classes retained their lead throughout, and that the Modern 'D' stream was always at the bottom of the list. In only two tests, however (dictation and composition), did the Grammar and Intermediate classes retain their rank order completely. (Dictation and composition are of course the two aspects which would gain most from the allocation of a larger amount of time.)

In translation, a process never touched by the Modern School children (who had never before been asked to take a piece of French and write an equivalent piece of English), no less than three Modern classes outdid the Intermediate class.

The overall average mark for the Secondary Modern 'A' and 'B' streams was exactly the same as the overall average for the Intermediate School class. One might almost base an argument for the

inclusion of a language in the Modern School curriculum on this result alone.

Two 'D' stream pupils, of I.Q. 84 and 82, scored higher aggregates than a boy from the Intermediate class, I.Q. 118.

Twenty-two Modern School pupils scored higher than the Grammar/Intermediate school average. (That is, over 10 per cent.)

Only 16 Modern School 'A' and 'B' pupils scored lower than the lowest Intermediate School score. (That is, under 10 per cent.)

I think it is true to say that if comparable results had been achieved in say History, Geography, Music or Biology, the teacher would have been quite pleased. Some difference is to be expected, obviously, between the achievement of Grammar and Modern School pupils, but no-one suggests that these other subjects should for this reason be excluded from the Modern curriculum.

(An interesting by-product of the test results was the relation shown between I.Q., English attainment, and French scores. Between I.Q. and French the correlation was 0·78, which is not a very close relationship; between English and French it was 0·85, which is much closer. This suggests that where it is necessary to select pupils for language learning, their English ability is a better prognostic of success than their I.Q.)

Conclusions

The conclusion to be drawn is that there is no special reason why a language should be regarded as more difficult than other subjects for children of average and below-average ability. Children of I.Q. 100 or over can generally be assumed as certain to make a successful study of a language. Children in the I.Q. range 80 to 100 can make worth-while progress. Children of I.Q. 70 to 80 can enjoy the study and progress in it as well as they do in other subjects.

In other words, if we do exclude large numbers of our children from learning languages, we must admit that it is perhaps for economic reasons, or for lack of teachers, or for lack of time, but not because of lack of ability on the part of the children.

However, I feel I must stress that I feel sure that these results and conclusions depend entirely upon the language being taught by rigorous active-oral methods.

BOOKS

The Making of Man. I. W. Cornwall and M. Maitland Howard. (Phoenix House, 1960.) 63 pp. 10*s.* 6*d.*

This is probably the most concise introduction to early man in existence and is sure to appeal to the many people nowadays who demand anthropology without tears. It is so clearly written that an intelligent 12-year-old would have no difficulty in following and enjoying it; there should certainly be a copy in every school library. Even the serious student, though he would have to go elsewhere for the details, will be grateful for such an excellent summary of the evolution of the hominids.

The story begins with the meaning of evolution and goes on to the preservation of fossils, methods of dating, and climatic changes during the Pleistocene. The account of the primates and their origins, including the great apes and their ancestors *Proconsul* and *Oreopithecus*, is followed by the history of the hominids from *Australopithecus* to the Old Man of Cro-Magnon. Miss Maitland Howard's attractive drawings, which adorn nearly every page, show the actual fossil material in black, with the reconstructions in red. By this method, the reader is left in no doubt as to what is fact and what is informed imagination.

Many specialists will disagree with Dr. Cornwall over details, particularly the question of dating. He follows Prof. Zeuner, for instance, in placing the beginning of the Last Glaciation at 120,000 years ago rather than 70,000 years. In the Table (p. 21), the Australopithecines and *Pithecanthropus*

both make their first appearance during the Villafranchian, though there is no evidence that the latter at any rate existed as early as this. *Atlanthropus* is shown at the time of the Second Glaciation, whereas he is now considered to date from the beginning of the Great Interglacial. Rhodesian Man, from Broken Hill and Saldanha, is placed (albeit tentatively, with a dotted line) on the same level as the Steinheim and Swanscombe skulls in the Middle Pleistocene; both the faunal and the archaeological evidence, however, leaves little doubt that he is early Upper Pleistocene. The Swanscombe skull is placed firmly on the *sapiens* line 'quite distinct from the Neanderthal lineage' (p. 56), although many authorities now consider it to be an intermediate form and probably very similar to Steinheim. In spite of these few criticisms, the book is thoroughly recommended.

SONIA COLE.

The Complete Scientist. (Oxford University Press, 1961.) 162 pp. Cloth, 18*s*. Paperback, 12*s*. 6*d*.

The Complete Scientist is the report of a study by an Advisory Committee set up by the British Association for the Advancement of Science under the Chairmanship of Sir Patrick Linstead, F.R.S., Rector of the Imperial College of Science and Technology, and financed by a grant from the Leverhulme Trust Fund.

The report is concerned with the problems, both quantitative and qualitative, of giving adequate weight to non-scientific subjects in the education both at school and university of students intending to become scientists or engineers or other technologists. The group concludes that the school curriculum is reasonably balanced below the sixth form but that it becomes distorted by too much specialisation both in the sixth form and at the university. This situation could be alleviated by the addition of a fourth year to the university course or by the establishment of post-graduate courses in the more specialised subjects. These solutions are regarded as being out of the question before about 1975, and the view is therefore expressed that a broader education for scientists and technologists must be achieved in the sixth form. The report accepts the need for specialisation at school but believes that the amount of time devoted in practice to non-scientific subjects is quite inadequate and should be considerably increased.

The report is one which should be read with interest and profit by all those concerned with the major problems facing education today and, in particular, with the task of educating students and future citizens for the world which confronts them.

The Major Achievements of Science. 2 vols. Demy octavo. Vol. I, xvi+368 pp.; vol. II, xii+196 pp. By A. E. E. McKenzie. (C.U.P.)

The author of these books, who is much concerned with the provision of an adequate view of scientific progress for the student, whether he be on the arts or science side, has certainly given a splendid means of enlightenment. Taking a broad sweep, from science and technology in ancient times, beginning with the elementary techniques of palaeolithic man, he deals with the Greek atomists, the rise of Arabian science and the developments and re-introductions of science during the Middle Ages and the Renaissance.

Such a sweep demands considerable breadth of knowledge and this must be greatly increased when one comes to the last three hundred years of scientific progress. The invention of the telescope gave an immediate impetus to new studies and the great increase in knowledge with which the name of Galileo (who made his own telescope) is associated. Similarly the invention of the microscope gave a new insight to a world of nature that had largely been unsuspected. Newtonian physics put the stars in their theoretical courses, the heroic age of geology transferred much of the new physics to the study of earth itself and both provided the basis for an advance in biological knowledge that led to Darwin and *The Origin of Species*.

On this far from simple route were many side roads. Robert Boyle and the development of chemistry; the making of vacua that occupied von Guericke (who also made the first reconstruction of a fossil vertebrate); Harvey and the circulation of the blood; and the wave theory of light are but some of the things encountered on the way, separate events here made part of the great mosaic that is modern science. Lysenko's theories and the Piltdown skull are less scientific things also discussed.

The text is lucid and well suited to the audience

the author has in mind. Since Einstein himself remarked that the way in which men reached their ideas was often as important as the ideas themselves, there is a great deal to be said for the historical introduction to science. Volume I gives this but the author has greatly added to the usefulness of his work by providing, in the second volume, the actual sources of many of the discoveries in their author's own words, starting with Aristotle's *Physics* and ending with C. D. Darlington's *Freedom and Responsibility in Academic Life*, written in 1957.

There are twenty-four plates in the first volume, a well-chosen bibliography and a good index, so the whole work itself represents a major achievement in the presentation and the popularisation of science.

W. E. S.

NEW BOOKS FOR THE GENERAL READER

The following notes are published by courtesy of the National Book League. They will be reprinted in the next annual supplement to SCIENCE FOR ALL, *an annotated reading list for the non-specialist, published for the N.B.L. by the Cambridge University Press.*

HISTORY OF SCIENCE

Harris, Ronald W., *comp.* SCIENCE, MIND AND METHOD. *Blackwell*, 1960, 9*s.* 6*d.* viii, 116 pp.

A brief introduction to 'some of the chief problems and methods which have occupied the minds of scientists and philosophers in different ages', presented in the form of extracts from the works of twenty-nine writers, with a concise introduction outlining the significance of each. Points for discussion are suggested. (500)

McKenzie, A. E. E. THE MAJOR ACHIEVEMENTS OF SCIENCE. 2 vols. *C.U.P.* Cased, Vol. 1: library edn. 30*s.* net; school edn. 20*s.* non-net 384 pp. 24 plates, 63 text figs. Vol. 2: A Selection from the Literature; library edn. 17*s.* 6*d.* net; school edn. 12*s.* 6*d.* non-net. 208 pp. 9 line drawings.

A most attractive history of the development of the main generalisations of science, their philosophical implications and their influence on Western thought. Biographical sketches of outstanding scientists are included.

Vol. 2 contains ninety-one extracts from the literature of science to illustrate Mr. McKenzie's themes. These extracts are comprehensible to the general reader and have been chosen for their liveliness and human interest as well as for their scientific value. Each extract has a brief note describing its origin and importance. (500)

CHEMISTRY

Seaborg, Glen T., and Valens, Evans G. ELEMENTS OF THE UNIVERSE. *Methuen*, 1960, 28*s.* 253 pp.

Half-tone illus. in the text throughout.

A stimulating and lavishly illustrated American presentation of the science of chemistry (based on a film series). Formulae are explained in a memorable way. Large type and wide margins contribute to ease of reading. Professor Seaborg was co-discoverer of nine of the 102 chemical elements and is a Nobel Laureate chemist. (540)

ASTRONOMY AND ASTRONAUTICS

Boyd, R. L. F. SPACE EXPLORATION BY ROCKETS AND SATELLITES. *Hutchinson* (*Basic Science*), 1960, 10*s.* 6*d.*; paperback, 5*s.* 128 pp.

A brief but not over-simple account of the development of rockets and satellites, the extent of our knowledge in this field at present, and the outstanding problems ahead. (551.5)

King, H. C. ASTRONOMY. *Vista Books* (*Illustrated Science*), 1960, 25*s.* 256 pp. Full-page and text illus., many in colour.

A 'broad view' of astronomy for the layman. The historical background is given and present knowledge of the sun, moon, planets, comets and meteors, and stars simply stated. A final chapter

tells of developments in space flight. The illustrations are from photographs and imaginative paintings and drawings by Terry Maloney. The author is Chief Astronomer in the London Planetarium. (523)

Thiel, Rudolf. AND THERE WAS LIGHT: the discovery of the universe. *Muller* (*Mentor Books*), 1960, paperback, 6*s*. 384 pp. Over 125 half-tone and line illus.

A full account of the problems solved by astronomers, from the earliest records to the present day, with biographical and social background. About a quarter of the book deals with modern developments. (Hard cover edition published by *Deutsch*, 1958). (520)

OCEANOGRAPHY

Burton, Maurice. UNDER THE SEA. *Vista Books* (*Illustrated Science*), 1960, 25*s*. 255 pp. Full-page and text illus., many in colour.

A popular but authoritative introduction to life in the ocean. Most of the illustrations are drawings and paintings by Maurice Wilson. (574.526)

Carrington, Richard. A BIOGRAPHY OF THE SEA: the story of the world ocean, its animal and plant populations, and its influence on human history. *Chatto & Windus*, 1960, 30*s*. xvi, 286 pp. 32 plates, maps, diagrams.

This book covers much the same ground as Dr. Burton's UNDER THE SEA, but at greater length and for a rather more sophisticated readership. The structure of the oceans, their physical and chemical aspects, waves, currents and climatic influence are introduced. The main part of the book describes the sea as an environment for life and the great variety of plants and animals at different levels. Birds, reptiles and mammals dependent on the sea are included. In the third part Mr. Carrington considers the relationship of man to the sea and describes some of the voyages of early navigators and the development of sea fisheries. Fish are dealt with in more individual detail than in R. C. Cowen's book below. Good bibliography. (574.526)

Cowen, R. C. FRONTIERS OF THE SEA: the story of oceanographic exploration. *Gollancz*, 1960, 25*s*. 307 pp. 21 photographs, 54 text figures.

This book provides more than its title promises. It does deal with the development of the science of oceanography, but its main contribution is a detailed (not too technical) survey of present knowledge of the chemistry, geology and biology of the sea. Waves, currents and climatic influence are discussed. The environmental conditions and range of life at different levels are described. Food potentialities and aquaculture are considered. The writing is taut. FRONTIERS OF THE SEA combines a scientific approach with something of the excitement of nineteenth-century explorers. It will appeal to professional as well as to general readers. The index and bibliography are disappointing. (551.46)

BIOLOGY

Hanrahan, James S., and Bushnell, D. SPACE BIOLOGY: the human factors in space flight. *Thames & Hudson*, 1960, 35*s*. vii, 263 pp. 12 plates.

A study by two Americans of the problems the human body will encounter in space flight (acceleration, weightlessness, radiation, breathing, eating and disposal of wastes, solitude in a sealed cabin), and the experiments necessary to solve them. This book will be of interest primarily to technologists and medical men, but is within the reach of the interested layman. (629.138)

Smythe, R. H. THE FEMALE OF THE SPECIES. *Country Life*, 1960, 21*s*. 144 pp. 7 drawings by Enid Ash.

A study of the part played in nature by the female in both human and animal spheres. (591.56)

ZOOLOGY

Alpers, Antony. A BOOK OF DOLPHINS. *Murray*, 1960, 15*s*. 147 pp. 16 plates.

An informal but comprehensive study of dolphins—the legends about them (Greek and Polynesian), their habits and life cycle, their intelligence and friendliness. (599.53)

Burton, Maurice. IN THEIR ELEMENT: the story of of water mammals. *Abelard-Schuman*, 1960, 12*s*. 6*d*. 13 photographs, drawings by Jane Burton.

A simply-written account of the lives of whales, seals, otters, hippopotamuses, sea-cows, beavers, water voles, water rats and platypuses. (599)

Cloudsley-Thompson, J. L. ANIMAL BEHAVIOUR. *Oliver & Boyd*, 1960, 15*s*. xiv, 161 pp. 16 half-tone plates, 75 drawings.

'The complex interactions between physiology and environment that form the basis of behaviour in higher forms have been analysed and illustrated by comparison between the simple reactions of lower animals, the rigid instincts of insects, fishes and birds . . .and the more plastic type of behaviour found in mammals . . .' (Author's Preface). ANIMAL BEHAVIOUR, based on first-hand observation as well as familiarity with the results of other research workers, is for serious students as well as for the general reader. It is illustrated with delightfully revealing photographs and drawings. The author, sometime lecturer in Zoology, King's College, London, is now Professor of Zoology in the University of Khartoum. (591.51)

Hutchins, Ross E. INSECTS: builders and craftsmen; hunters and trappers. *Burke*, 1960, each 12*s*. 6*d*. 96 pp. 70 photographs.

These two together form an attractive popular introduction to the study of insects and their behaviour. Based on American species. (595.7)

BOTANY

Hutchins, Ross E. STRANGE PLANTS AND THEIR WAY. *Burke*, 1960, 12*s*. 6*d*. 96 pp. 60 photographs.

Eleven chapters on various 'strange plants' in different parts of the world.

Kingdon-Ward, Frank. PILGRIMAGE FOR PLANTS. *Harrap*, 1960, 18*s*. 191 pp. 21 pp. photographs.

A professional plant-collector describes expeditions in Assam, Burma, China and Tibet. PILGRIMAGE FOR PLANTS blends autobiography with speculations on plant-geography and first-hand accounts of the discovery of various plants and their introduction to gardens. (581.959)

Wolff, Leslie. SCIENCE AND THE FORESTER. *Bell*, 1960, 15*s*. 159 pp. 16 photographs, drawings by Kerry Lee.

An introduction to the history of trees and the science of forestry, in documentary style, based on the experiences of a young forester. (634.9)

TECHNOLOGY

Abbott, W., *ed*. THE YOUNG SCIENTIST. *Chatto & Windus*, 1960, 15*s*. 320 pp. Photographs and line illus. in the text.

Twenty articles on different aspects of applied science, primarily intended for readers of 13 to 19. Contributors include Sir Harold Hartley on Machines that control machines, Nigel Calder on Transistors, Professor W. J. Duncan on High-speed flight, K. N. Hawke on Stereophonic reproduction of sound, etc. (600)

Baker, W. J. THE YOUNG MAN'S GUIDE TO TELEVISION. *Hamish Hamilton*, 1960, 15*s*. 223 pp. Illus.

In two parts: the first covers historical aspects, from experiments as long ago as 1880; the second sets out the basic principles of transmission and reception (including colour television and closed circuit). A final chapter deals with careers in the television industry. (621.388)

Croome, Angela. HOVER CRAFT. *Brockhampton Press*, 1960, 15*s*. 72 pp. Illus. in the text throughout.

Written for teenagers, this book will be attractive also to mechanically minded parents. The development of 'hover craft' is described, from Leonardo da Vinci's ornithopter, through autogiros and helicopters to Cockerell's hovercraft. The last-named is described in detail, and there is a whole chapter on how a helicopter flies. (629.133)

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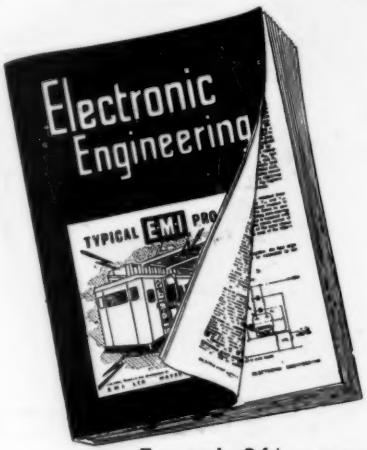
THE DIRECTORY OF NATURAL HISTORY AND FIELD STUDY SOCIETIES

THE Council of the British Association for the Advancement of Science have, at the invitation and with the financial backing of the Carnegie United Kingdom Trust, prepared a new edition of *The Directory of Natural History Societies* which was first published in 1948 by the Amateur Entomologists Society.

The Directory covers archaeological, astronomical, biological, botanical, geographical, geological, meteorological and zoological societies, both national and local amateur bodies —and other cognate societies. The information given for each society is listed under the following headings: title and address, name and address of Secretaries, aims and objects, conditions of membership, amenities, meetings, publications and affiliations. Societies are arranged alphabetically under the main headings of natural history, archaeology, archaeology and natural history, societies with general interests, geology, astronomy, and meteorology. The arrangement of the societies within the sections is strictly alphabetical according to the titles supplied by the Secretaries. There is a final geographical reference section in which the names of the societies are listed alphabetically according to counties.

Copies of the *Directory* are available to all Natural History and Field Study Societies at a price of 10*s*. (post free) from The Secretary, British Association for the Advancement of Science, 18 Adam Street, Adelphi, W.C.2.



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A Symposium held at the National Physical Laboratory on 9th, 10th, and 11th June 1959

The eleventh in the present series, this symposium was designed to provide an opportunity for physicists interested in metrology, optics, radio and radiation to meet and discuss recent developments in interferometry and the application of its principles in these diverse branches. During the five sessions 21 papers were presented and discussed and this volume gives a fairly complete and concise record of all the proceedings. Illustrated with plates and text drawings. **30s.** (*post 1s. 9d.*)

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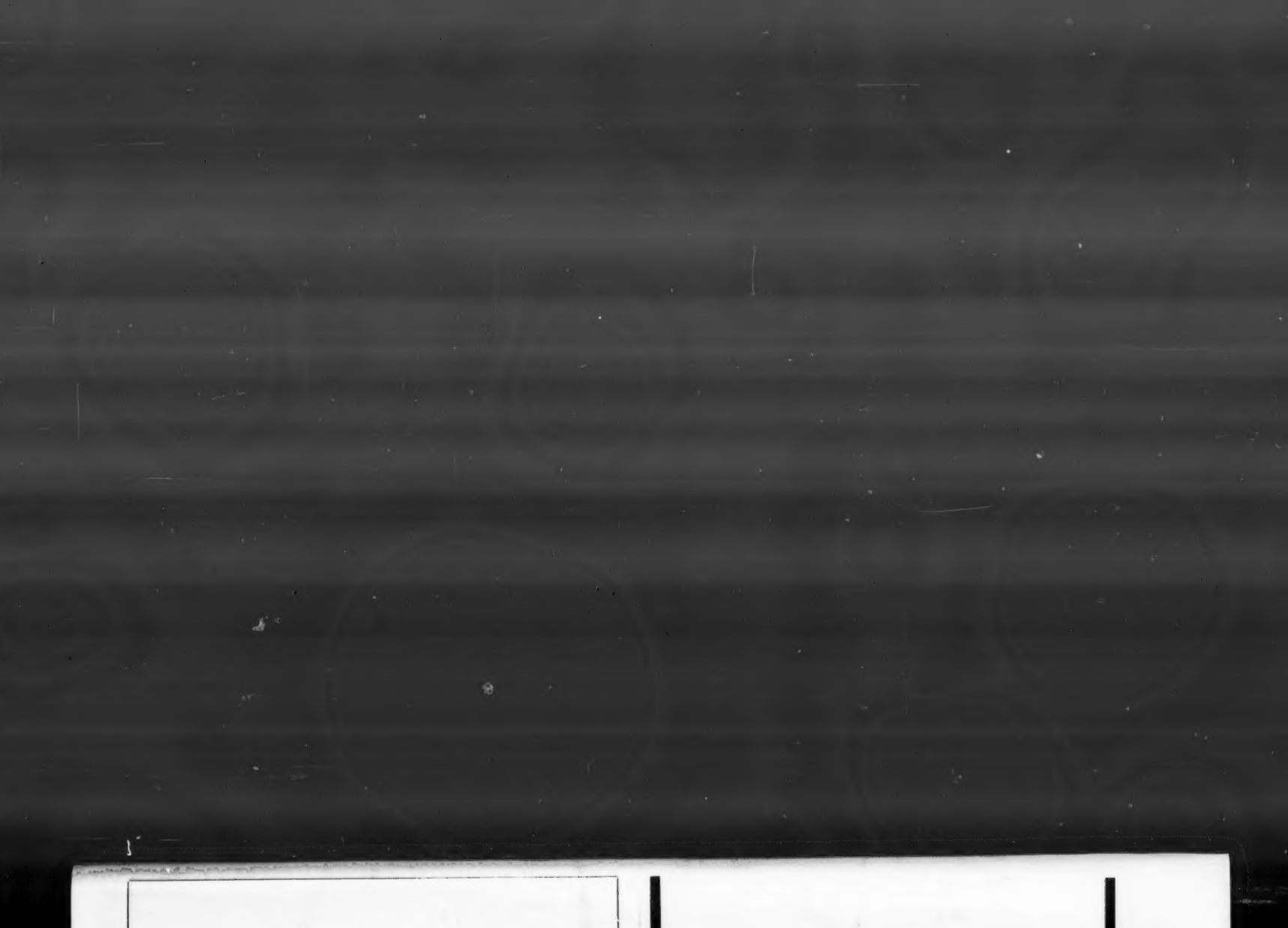
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